DOCUMENT RESUME

ED 061 710 EM 009 616

AUTHOR	Charles, John P.; Johnson, Robert M.
TITLE	Automated Training Evaluation (ATE). Final Report.
INSTITUTION	LOGICON, Inc., San Diego, Calif.
SPONS AGENCY	Naval Training Device Center, Orlando, Fla.
REPORT NO	NAVTRADEVCEN-70-C-0132-1
PUB DATE	Jan 72
NOTE	165p.
EDRS PRICE	MF-$0.65 HC-$6.58
DESCRIPTORS	*Automation; *Computer Assisted Instruction; Digital Computers; Educational Specifications; *Feasibility Studies; Flight Training; *Military Training; Simulators; Task Analysis; Technological Advancement; *Training Techniques

ABSTRACT

The automation of weapons system training presents the potential for significant savings in training costs in terms of manpower, time, and money. The demonstration of the technical feasibility of automated training through the application of advanced digital computer techniques and advanced training techniques is essential before the application of such techniques is warranted. The advanced computer techniques include the incorporation of real time performance monitoring and course scheduling. The advanced training techniques center on the feasibility of adaptive training based on performance measurement reflecting operational performance requirements. Automated Ground Controlled Approach and emergency procedures tasks were implemented on the Naval Training Device Center-Training Device Computer System (TRADEC system) and tested with operational pilots. The results demonstrated the feasibility of automated training as well as the acceptance of the training technique by operational personnel. Recommendations for the testing of the effectiveness and efficiency of the techniques are made. (Author)

ED 061710

Technical Report: NAVTRADEVCEN 70-C-0132-1

AUTOMATED TRAINING EVALUATION (ATE)

John P. Charles
Robert M. Johnson

LOGICON, Inc.
1075 Camino Del Rio South
San Diego, California 92110

Contract N61339-70-C-0132
NAVTRADEVCEN Task No. 8175-2

January 1972

DOD DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

NAVAL TRAINING DEVICE CENTER

ORLANDO, FLORIDA

ABSTRACT

The automation of weapons system training presents the potential for significant savings in training costs in terms of manpower, time, and money. The demonstration of the technical feasibility of automated training through the application of advanced digital computer techniques and advanced training techniques is essential before the application of such techniques is warranted. The advanced computer techniques include the incorporation of real time performance monitoring and course scheduling. The advanced training techniques center on the feasibility of adaptive training based on performance measurement reflecting operational performance requirements. Automated Ground Controlled Approach and emergency procedures tasks were implemented on the Naval Training Devices Center-Training Device Computer System (TRADEC System) and tested with operational pilots. The results demonstrated the feasibility of automated training as well as the acceptance of the training technique by operational personnel. Recommendations for the testing of the effectiveness and efficiency of the techniques are made.

FOREWORD

This document reports the results of a successful attempt to automate GCA training in an aircraft simulator.

The work was conducted as a part of Project 8504 "High Performance Aircraft Crews" of Technical Development Plan N43-08X.

The results clearly demonstrate that automated instruction is technically feasible and that the state-of-the-art of digital systems and training methodology are adequate for implementation of automated, individualized training.

James S. Duva

JAMES S. DUVA
Project Psychologist

ACKNOWLEDGMENTS

The success of this project was the result of the efforts and cooperation of many people. Of significant value was the participation of personnel of U.S. Navy Fighter Squadron 101, Naval Air Station, Oceana and U.S. Air Force 46th Tactical Fighter Squadron, McDill Air Force Base.

Particular thanks are due to the support provided by the Naval Training Device Center Code 54 personnel — Jack Booker, Fred Cooper, Richard Diddle, Jim Glatt, Hal McKinney, Harvey Saltzman -- without whose efforts the work reported here could not have been accomplished.

CONTENTS

CONTENTS (Continued)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

SECTION I

INTRODUCTION

1.0 BACKGROUND

In 1969, the Naval Training Devices Center initiated a program to demonstrate that the effectiveness of training devices could be increased through the application of recent advances in engineering technology and training methodology. As part of this effort Logicon, Inc., analyzed the feasibility of automating portions of weapon system trainers and prepared design guides for illustrative implementation on selected flight profile segments. (1) The F-4 trainer was chosen as a sample case. The initial effort consisted of a survey of typical trainers in operational use. It revealed that one of the most serious problems in the field use of these devices was the lack of a definitive curriculum supported by qualified instructors.

The other tasks of the study included the analysis of five selected flight and mission segments and the development of automated training approaches. The five segments included:

1. Instrument Flight Maneuvers.
2. Ground Controlled Approach (GCA).
3. Offset Bombing.
4. Navigation.
5. Takeoff, Climb and Emergency Procedures.

The review of on-going training utilizing WSTs revealed that in large:

1. WSTs were being used for cockpit orientation and procedures training.
2. There was no well-defined training approach for utilizing WSTs.
3. There was a lack of performance criteria and measurement.
4. The instructor's role was not well defined. Their approach to training varied widely, especially in student evaluation.

The review of the different mission and flight segments concluded that automation, although complex in many cases, was feasible and should be effective in terms of efficiently achieving the required student performance level. The incorporation of adaptive training techniques was seen as a particularly significant approach to minimizing training time.

The U. S. Air Force recently completed a related study (2) directed to the development of different approaches to implementing automated training capabilities. The following eight training capabilities were studied:

1. Automatic malfunction insertion.
2. Automatic variation of task difficulty.
3. Automatic student feedback and guidance.
4. Automatic permanent recording of results.
5. Automatic monitoring of procedural items.
6. Automatic sequencing of maneuvers and mission segments.
7. Automatic instructor feedback.
8. Automatic demonstration.

Implementation costs were developed. The application of any of the capabilities analyzed could therefore be evaluated in terms of computer requirements and related costs. It was also recognized that "Each capability area must be proven, i. e., in relation to its training value, prior to installation for ground training." (3)

11

SECTION II

STATEMENT OF THE PROBLEM

2.0 GENERAL

The 1969 Logicon, Inc., study (1), while indicating the theoretical feasibility of automating many WST functions, pointed out that demonstration of technical feasibility and of effectiveness would be required to justify application to operational trainers. Moreover, the potential benefits which could be derived from adaptive automated training and the advanced state-of-the-art of training methodology were considered to warrant immediate test.

2.1 RELATED PROBLEMS

Three kinds of application feasibility are normally identified. These reflect consideration of:

1. Technical feasibility.
2. Usefulness.
3. Financial acceptability or effectiveness.

While they are obviously interrelated, they answer the questions:

1. Can the concept be implemented?
2. If implemented, will it solve a need or requirement?
3. If it does solve a need, is the output worth the cost?

While all three questions can sometimes be answered in a single test, it is typically more economical to answer specific technical feasibility questions before conducting a parametric test of usefulness and effectiveness. This results from the fact that normally only limited aspects of the concept require technical feasibility test. The majority of the system may consist of already proven subsystems. Therefore only the advanced techniques require test and then only at an implementation feasibility level.

When this "risk" has been favorably resolved, a full scale experimental test of the advanced system is justified.

The major technical problems involved in automated adaptive training are seen as:

1. The development of computer programs which can evaluate student performance and restructure the training course in real time.

2. The implementation of a crew station simulation with computer control of all training steps and functions.

It goes without saying, that given enough computer memory, programming skill, time, and money, the problems could be solved. Obviously such an approach would be neither financially acceptable nor productive in a practical sense. Technical feasibility requires solution within the real world of weapon system training.

2.2 PROBLEM STATEMENT

The problem was therefore identified as one of implementing sufficient automated weapon system training to demonstrate technical feasibility in terms of computer programs and crew station development within realistic and practical constraints.

SECTION III

METHOD

3.0 GENERAL

The demonstration of technical feasibility requires a systems engineering approach to achieve effective implementation and an objective evaluation. Especially important is a detailed problem definition and an analysis of application areas to ensure that the task selected for demonstration has sufficient scope to be representative as well as predictive. Thus, while the problem was identified as mainly one of computer program and crew station development, the initial steps involved identifying a training task of sufficient breadth to demonstrate automatic training with confidence that predictions to operational weapon system training could be made.

The basic approach involved five major steps or phases:

1. Problem Definition - Phase A.
2. Analysis - Phase B.
3. Design and Development - Phase C.
4. Implementation and Debug - Phase D.
5. Test and evaluation - Phase E.

3.1 PHASE TASKS

Each of the phases involved a series of subtasks.

3.1.1 Problem Definition Tasks

The definition phase typically poses a paradox. A problem is difficult to state until it is understood, yet the problem is not truly understood until it is solved. Obviously, the two steps must be conducted simultaneously. This does not minimize the importance of a system operational requirement which can and should be objectively stated. The paradox occurs at the design level, where the requirement is translated into engineering terms. While the translation can be relatively easy for a system engineering development. It is difficult at best for advanced system or concept demonstration where the operational requirement is poorly understood or defined. Therefore, the definition phase is extremely important to the success of the demonstration of advanced systems.

Practical constraints help both to define the demonstration required and to delimit the problem. Three such major factors were isolated for the automatic training demonstration. These were:

1. The use of an existing simulation device would be necessary. The cost of building a special device would be totally unacceptable.

2. A training task would be required which could be completed in a relatively short period of time, yet be relevant to naval training problems.

3. A local source of students for demonstration test would be required.

The review of feasible simulators resulted in the selection of the Training Device Computing System (TRADEC System) at the Naval Training Devices Center. This system which was designed for Research and Development efforts, has the flexibility required for experimental tasks, and most importantly, could be modified and scheduled relatively easily. While validity considerations favored utilization of an operational trainer, past experience indicated that modification of such a trainer and its syllabus, much less implementing the required control of student input and related variables, poses virtually insurmountable problems. Trainer "down time" to implement a development program would pose an unacceptable requirement to any training organization.

Once the TRADEC System had been selected, the training task had to be at least bounded in scope and content. The TRADEC System includes a simulated single seat fighter type aircraft without a weapons system. The F-4 aerodynamic equations are utilized. Figure 1 is a block diagram of the major subsystems. The ones of interest at this point included the motion system and the COGNITRONICS speechmaker. The latter device assembles a fixed vocabulary into phrases and sentences under computer control. The motion system is driven by the F-4 program contained in a XDS SIGMA-7 computer. Thus, the TRADEC System constrained the

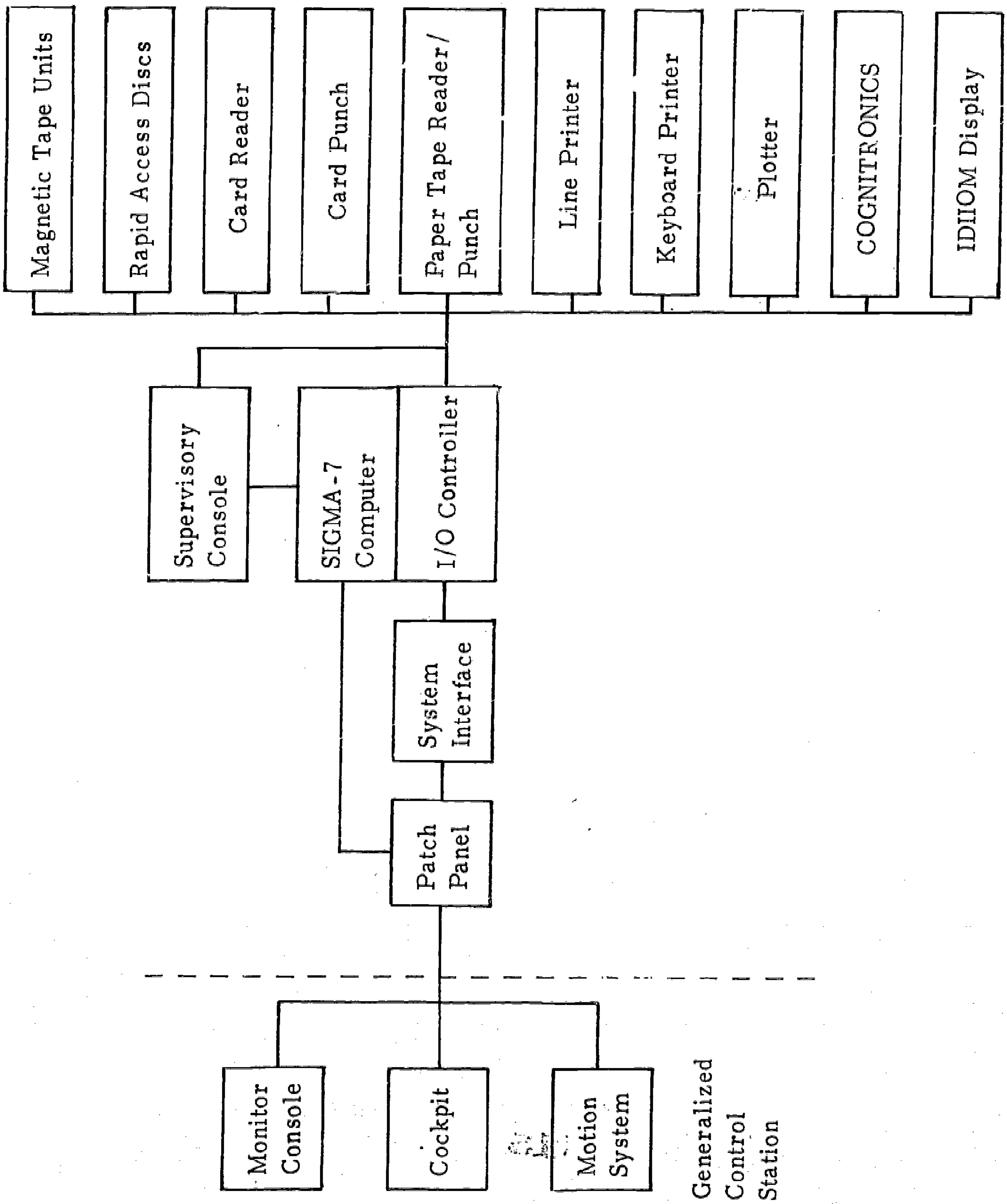


Figure 1. TRADEC System

training task to a basic fighter aircraft task with oral command capability. Instrument flight would be required since visual projection equipment was not installed. Once these basic considerations had been resolved, the remaining typical tasks for a definition phase were completed. These included:

1. Definition of Constraints.
2. Definition of Feasible Training Tasks.
3. Analysis of the TRADEC System.
4. Selection of Best Training Task and Plan.

Criteria were developed for selection of the training task. The basic set included:

1. Task difficulty must be controllable.
2. Task performance must be objectively measurable.
3. Task must be relatively short, i.e., less than 15 to 20 minutes.
4. Task training must be implementible within the constraints identified.

A review of the flight segments analyzed in the earlier Logicon study (1) clearly indicated that the Ground Controlled Approach (GCA) was the most logical task to employ:

1. The task requires an elementary cockpit, i.e., no navigation or flight director system.
2. The task is performed under instrument flight conditions.
3. The task is a common operational task of fighter aircraft and is of relatively short duration

The COGNITRONICS Multiplex Speechmaker provided the solution to the GCA voice command input requirement.

Emergency procedures compatible with the GCA were selected for additional demonstration tasks. A review of F-4 aircraft emergencies resulted in the selection of two; 1) single engine failure, and 2) communication failure as feasible for implementation and compatible with the GCA task.

Potential student populations were reviewed. The requirements for a reasonable testing period and meaningful results for weapon system training or operational application dictated the use of qualified military pilots as the primary group. The addition of some novice pilots was planned to provide some information on automated training limitations.

In summary, the definition phase resulted in the selection of the Ground Controlled Approach and two related in-flight emergencies as the training tasks to be used with the TRADEC System.

3.1.2 Analysis Phase Tasks

The analysis tasks were fairly straightforward and included:

1. Analysis of TRADEC Simulation Software
2. Analysis of TRADEC Simulation Hardware
3. Analysis of the Training Task
4. Analysis of the Demonstration Plan

The detailed analysis of the TRADEC system was required for two major reasons. First, the automated training software would have to interface with the basic simulation program. Thus, it would have to be compatible with the F-4 program cycle time without distributing the basic simulation parameters. Secondly, the hardware analysis was required to insure that the cockpit was compatible with the task and that the TRADEC subsystem could be integrated into an automated training system. From the beginning it became obvious that some switching function while conceptually simple to automate, could be costly to implement. Therefore ground rules were established that discrete event actuations could be "simulated" if necessary, provided that no human modification of the action was required or could affect the demonstration. Thus, for example, the actuation of the tape recorders for briefings can best be handled manually. A signal could be provided to the system operator for this function.

The analysis of training tasks and training plans were to the depth required to identify the performance criteria, performance measures, task structure, typical operational environment, and task difficulty factors.

3.1.3 Design Phase Tasks

The functional descriptions developed during the analysis phase provided the foundation for the design and development of the computer program and training program. The end product was a design package which was used to implement the demonstration program. It included:

1. A detailed description of the test to be performed to demonstrate the automated training techniques.

2. The design and development of the software required for the demonstration.

3. Preparation of training schedules, data forms, and student briefing lectures.

4. Specification of the required changes to the existing TRADEC hardware/software to properly interface the proposed demonstration program.

5. The design of a test plan to adequately check out both the experimental concepts and the program itself.

3.1.4 Implementation and Debug Phase Tasks

This phase consisted of the initial program operation debugging, and the final verification of the test plan. The objective of this phase was to ensure that the evaluation program and especially the hardware and computer programs performed as designed.

3.1.5 Test and Evaluation Phase Tasks

The final phase of the project was concerned with the generation of sufficient data to successfully demonstrate the technical feasibility of automated training. It included analysis of the data and preparation of the final report.

3.2 TRAINING REQUIREMENT ANALYSIS

The Ground Controlled Approach was analyzed in depth to isolate the training task and support functions required. Standard terminology was collected and tapes of actual F-4 GCAs were recorded and reviewed. Handbooks on the F-4 and GCA systems including the SPN-35 and SPN-42 systems were studied.

The complete GCA includes both a vectoring mode (Airport Surveillance Radar (ASR)) and a precision approach mode (Precision Approach Radar (PAR)). It soon became clear that the vector mode although not technically difficult to mechanize would involve extensive modification of the F-4 software. Therefore, the final approach phase, PAR, was isolated for the flight task.

The major variables affecting the GCA were identified as:

1. Aircraft weight and drag changes.
2. Atmospheric turbulence.
3. Runway wind conditions.
4. Aircraft performance degradation.
5. GCA control degradation.

The information requirements of the pilot were identified as:

1. Primary:
    a. Aircraft attitude - pitch, roll, and yaw.
    b. Aircraft flight vector, glide slope, course, and range.
    c. Angle of attack.
    d. Engine tachometer
2. Secondary:
    a. Altitude.
    b. Rate of climb.
    c. Airspeed.
    d. Turn and slip.
    e. Engine instruments; fuel flow, fuel quantity, fuel pressure, exhaust gas temperatures, oil pressure etc.

f. Nozzle position.

g. Wheels and flaps indicators.

h. Caution and warning lights.

The controls required by the pilot were identified as:

1. Primary:

   a. Control stick.

   b. Rudder pedals.

   c. Trim controls.

   d. Throttles.

   e. Wheels lever.

   f. Flap control.

2. Secondary:

   a. Engine controls (master, ignition, etc.).

   b. Speed brakes.

   c. Lighting controls.

   d. Fuel system control.

The functions of the PAR controller were analyzed. The major functions involve providing the following information to the pilot:

1. Initiating instructions.
2. Glide path information.
3. Approach course information.
4. Range to go information.
5. Published decision height and minimum descent altitude.
6. Wave-off and missed approach instructions.
7. Special information such as wind, traffic, etc.

Appendix F is a summary of typical GCA PAR controller messages. Appendix G contains the phraseology utilized in this demonstration and differs in two respects from the standard:

1. ATE messages are fixed, i.e., no variation is possible in terms of word rate, priority, or voice inflection.

2. Vocabulary necessarily complies with the NTDS COGNITRONICS word list (Appendix E). Thus, for example, "Complete Landing Settings" was used in place of "Complete Landing Checklist" and "Precision Minima" in lieu of "Published Decision Height." While these changes were considered relatively inconsequential, the lack of rate and anticipatory phrases such as "going", "holding", "coming up", etc., precluded the mechanization of this type of information.

Figures 2 and 3 depict the glide slope and approach course geometry and mechanization requirements. In addition, heading correction information was required such that a pseudo-asymptotic approach to the GCA course could be directed.

In order to expedite the GCA runs, pilots were not required to "go-around" at the conclusion of each run. A series of successive "straight ahead" GCA profiles as depicted in Figure 4 were programmed to minimize run time.

The third major analysis concerned the total system requirements for automated GCA training. A detailed analysis of the training steps involved was conducted to ensure that all student and aircraft contingencies had been explored. Figure 5 depicts the basic training session in a first level flow diagram and identifies major support system functions required.

3.3 DESIGN OF THE SYSTEM

As discussed earlier, the goal was the demonstration of fully automated GCA training concentrating on final approach control and relevant emergencies within the identified constraints. Practical considerations dictated the philosophy that "simulation" of automation would be acceptable provided no response time delays or human decision making or response to the student could occur. This relegated any simulation of automation to switch operation only.

3.3.1 Function Analysis

A detailed analysis was conducted of the functions required for automated GCA training. Figure 6 is a flow chart of the functions identified and allocated to student, software, and other support systems. The latter involved five functions, three of which are briefing requirements. Initializing and resetting functions were allocated to the system

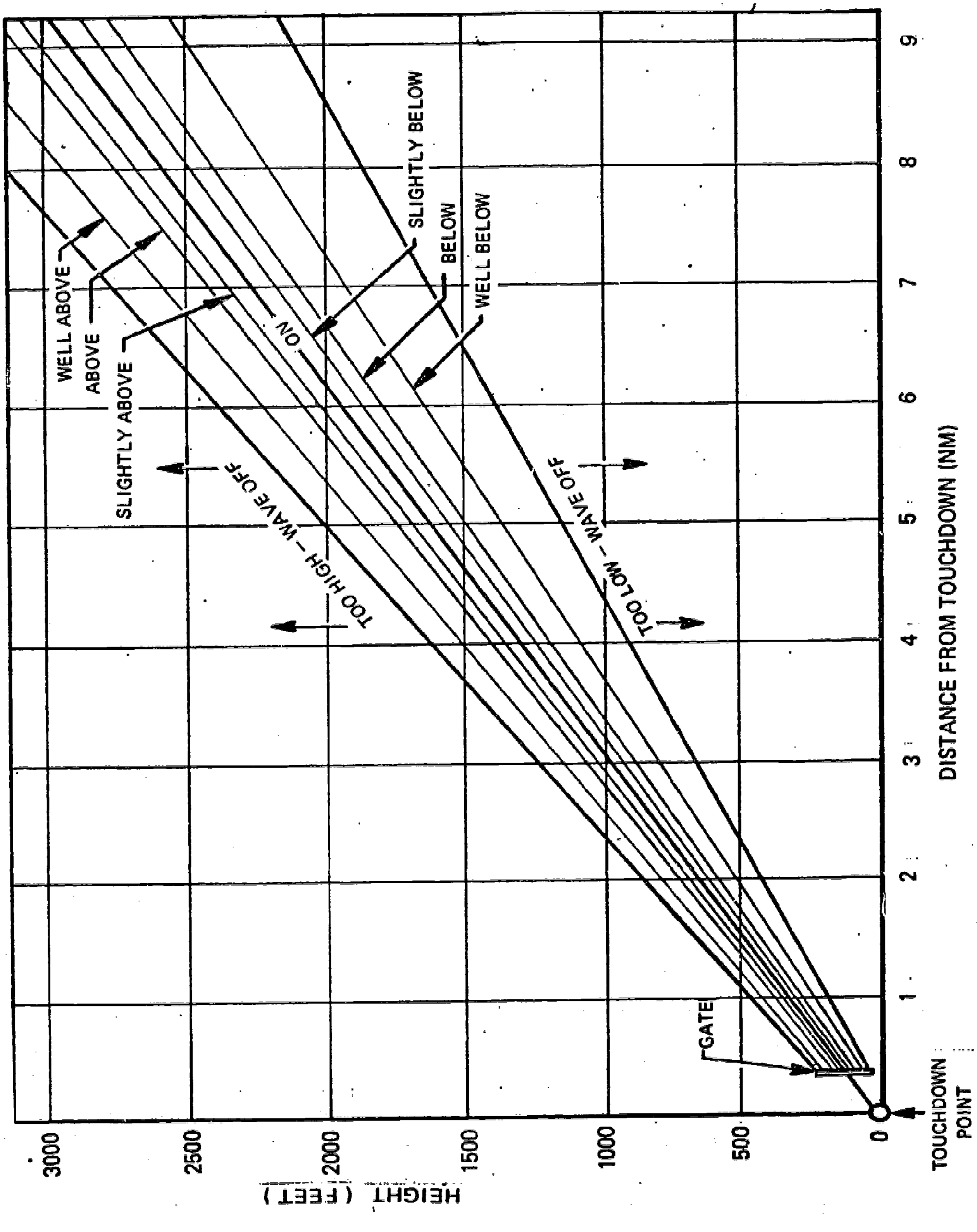


Figure 2. GCA Controller Glide Path Geometry

123

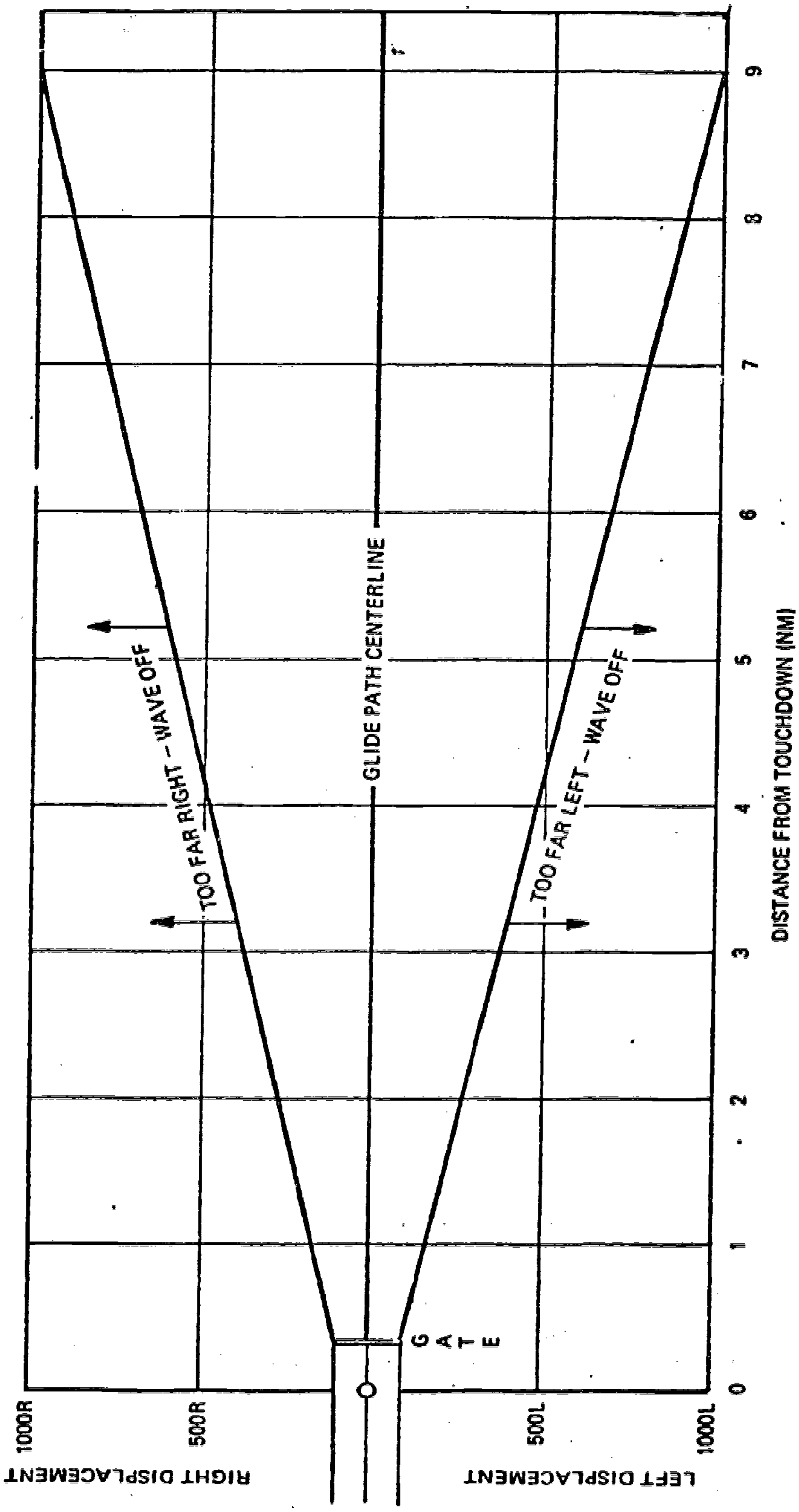


Figure 3. GCA Controller Approach Course Geometry

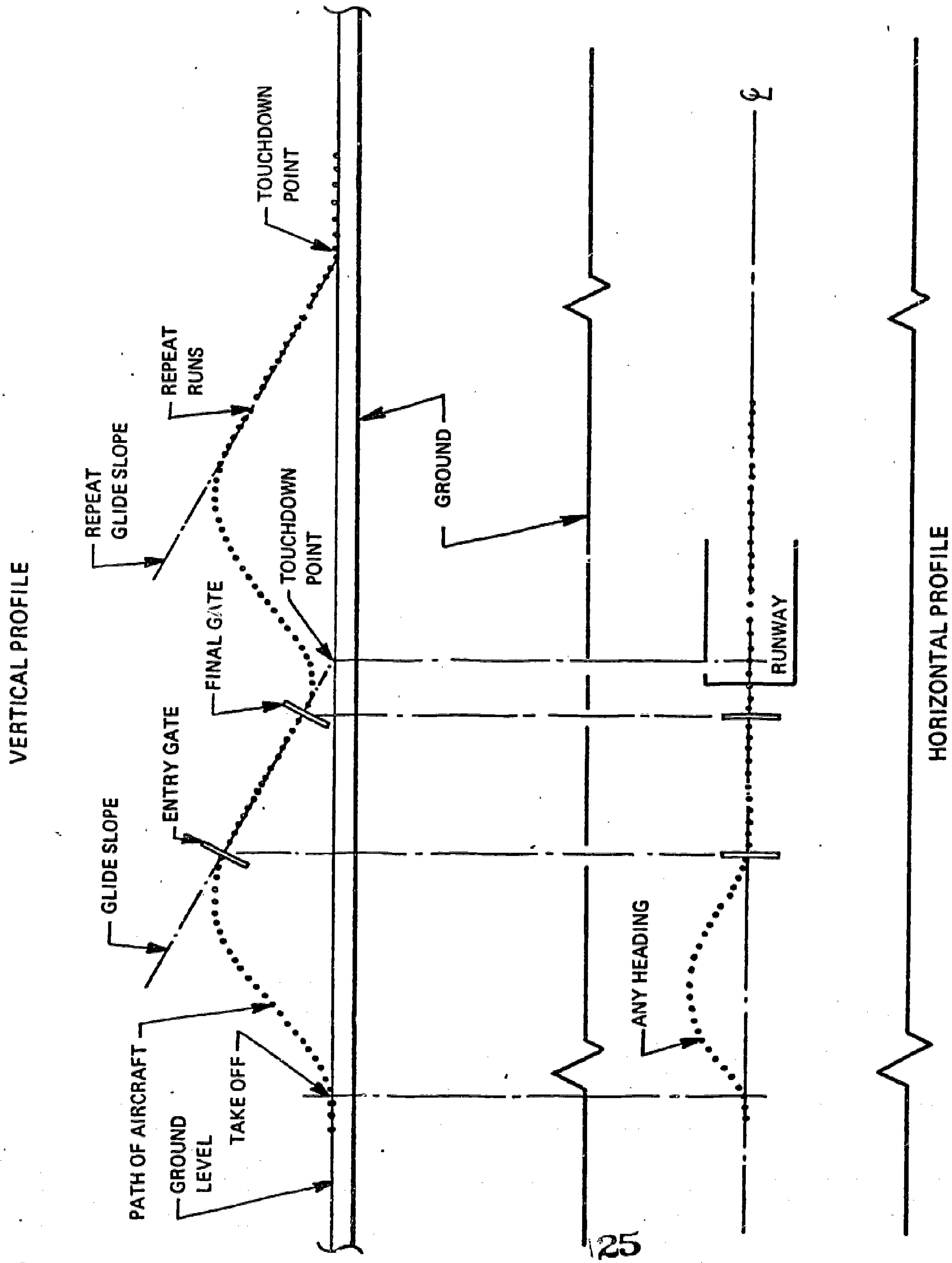


Figure 4. ATE Flight Profile

Student Steps	Training Support System Function
Student arrives for training	Identify student name, training background, training needs. Brief student appropriately. Direct student to cockpit as required.
Prepares for training	Brief student for exercises. Direct flight preparation. Check readiness. Direct take off.
Position for PAR control	Vector to PAR acceptance "Gate." Check configuration and flight conditions. "Trap" and engage PAR control.
Flies GCA passes	Provide glide path instructions. Provide approved course. Provide range. Provide wave-off instructions. Provide runway, wind, minimums, missed approach, and emergency information. Score pass performance. Structure course.
Flies emergency passes	Create emergency. Score emergency performance. Structure emergency training course.
Student completes course	Direct landing and shutdown
Debrief	Direct student to debrief. Summarize and store output data. Terminate training.

Major contingencies to consider:

1. Crash
2. Student fails to take directed action or configure aircraft as required.
3. Training support system failure or malfunction.

Figure 5. ATE GCA Training Steps

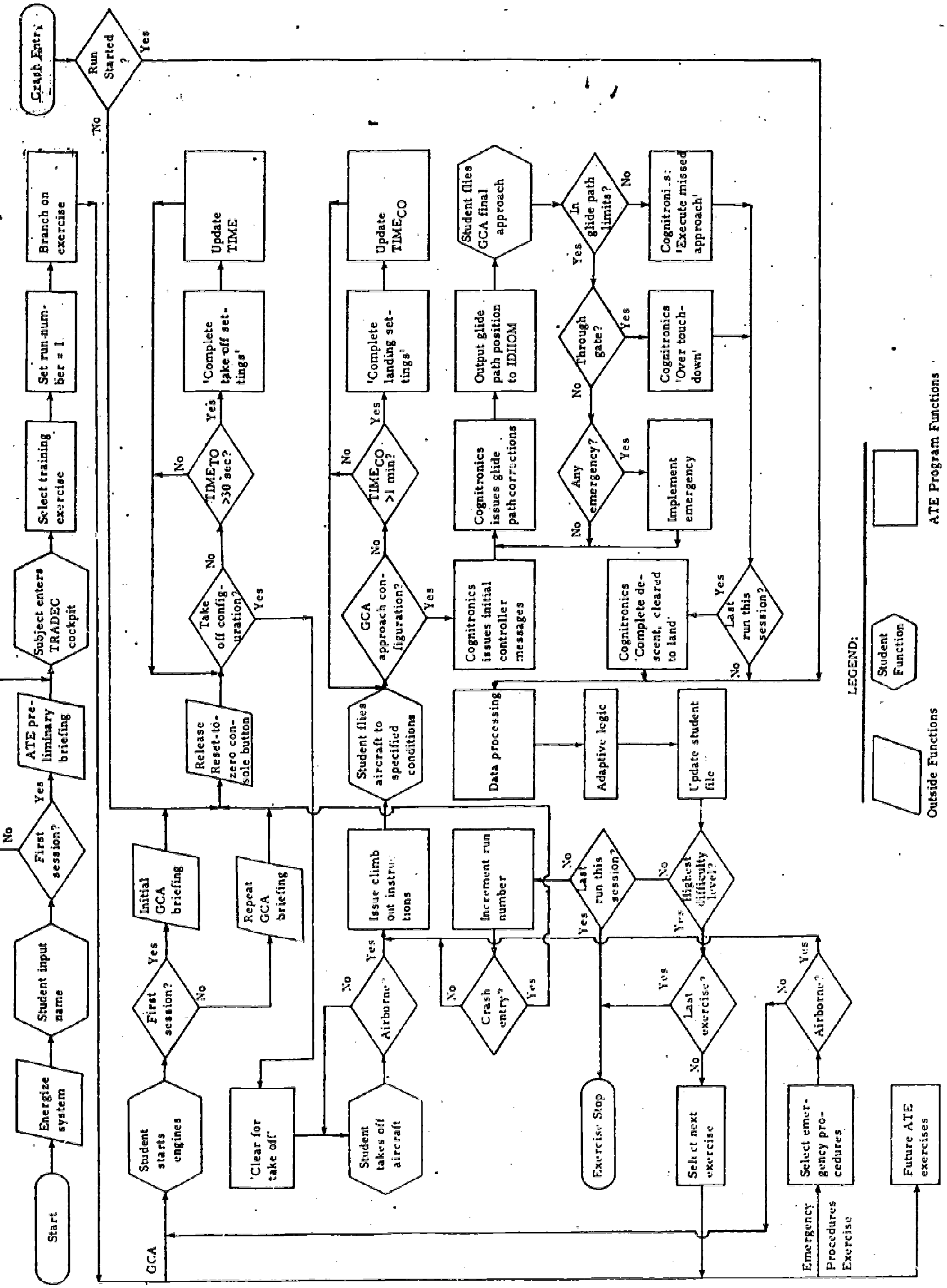


Figure 6. ATE Function Flow Diagram

operator. It is obvious that all of these functions could be incorporated into software except for requiring the student to "sign-in."

3.3.2 Training Plan Design

Three design tasks were required. The first involved the development of a sequence of GCAs of increasing difficulty; the second involved design of a system for scheduling the GCA; and the third involved development of a measurement system.

3.3.2.1 Training Course. A training course consisting of 38 different runs for GCA training and five for emergency procedures was designed. The analysis of the GCA requirements had produced three major difficulty factors. These were changes in aircraft weight and drag, atmospheric turbulence, and runway wind conditions. Five conditions and levels for each factor were selected. All reflected F-4 operational capability. The runway wind conditions selected were:

1. Level 1 - 30 knots head wind.
2. Level 2 - 15 knots head wind.
3. Level 3 - 2 knots head wind*.
4. Level 4 - 15 knots tail wind.
5. Level 5 - 30 knots tail wind.

Figure 7 illustrates the major effect of wind changes which is of course the time spent on the approach.

Weight and drag changes were effected by adding external stores to the aircraft. The F-4 has ten stations for hanging external stores. Once configured for a particular run, the configuration was "frozen," i.e., no fuel was consumed and stores could not be jettisoned or fired. The levels were achieved by the following conditions:

1. Level 1 - 1,000 lbs internal fuel.
2. Level 2 - level 1 plus full center line tank (station 5).

---

*Used instead of zero wind because of COGNITRONICS vocabulary restrictions.

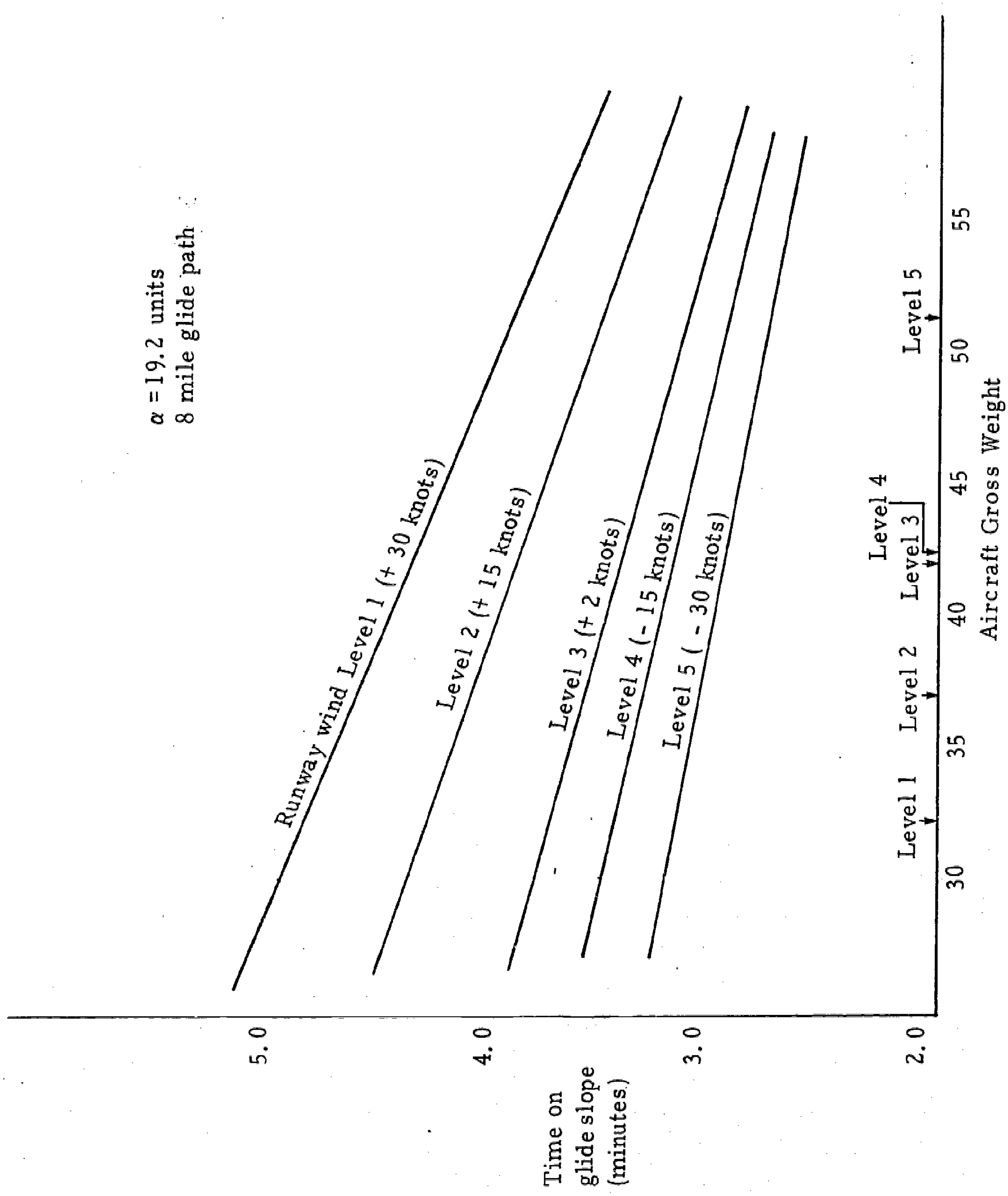


Figure 7. Minimum Time On Glide Slope

3. Level 3 - level 2 plus 2 full wing tanks (stations 1, 9).
4. Level 4 - level 3 plus 2 Sidewinder missiles (stations 2, 8).
5. Level 5 - level 4 plus 4 Sparrow missiles (stations 3, 4, 6, 7).

These stores resulted in aircraft gross weight as follows:

1. Level 1 - 32, 200 pounds.
2. Level 2 - 36, 200 pounds.
3. Level 3 - 41, 690 pounds.
4. Level 4 - 42, 070 pounds.
5. Level 5 - 51, 170 pounds.

The impact of these weights on length of the approach can be seen in Figure 7. Figure 8 shows the impact on approach speeds.

The third factor, turbulence, involved setting 5 levels of a random number generator input to the F-4 program. The actual settings used were:

1. Level 1 - no turbulence.
2. Level 2 - 4 percent of maximum turbulence.
3. Level 3 - 8 percent of maximum turbulence.
4. Level 4 - 12 percent of maximum turbulence.
5. Level 5 - 16 percent of maximum turbulence.

The maximum turbulence level (level 5) was established on the basis of qualified F-4 pilot opinion. The other levels were set in equal steps to the no turbulence condition.

Table 1 lists the 38 GCA trials in sequence for the training course. The allocation of difficulty factors reflected discussion with operational pilots and preliminary simulation runs with F-4 pilots.

The emergency runs were structured around single engine failure and communication failure. The F-4 is capable of single engine flight, although a failure at slow speed causes a significant yaw trim change. A communication failure calls for execution of a missed approach procedure if no message is received by the pilot over a period of 5 seconds while under PAR control. Table 2 lists the emergency run course. The

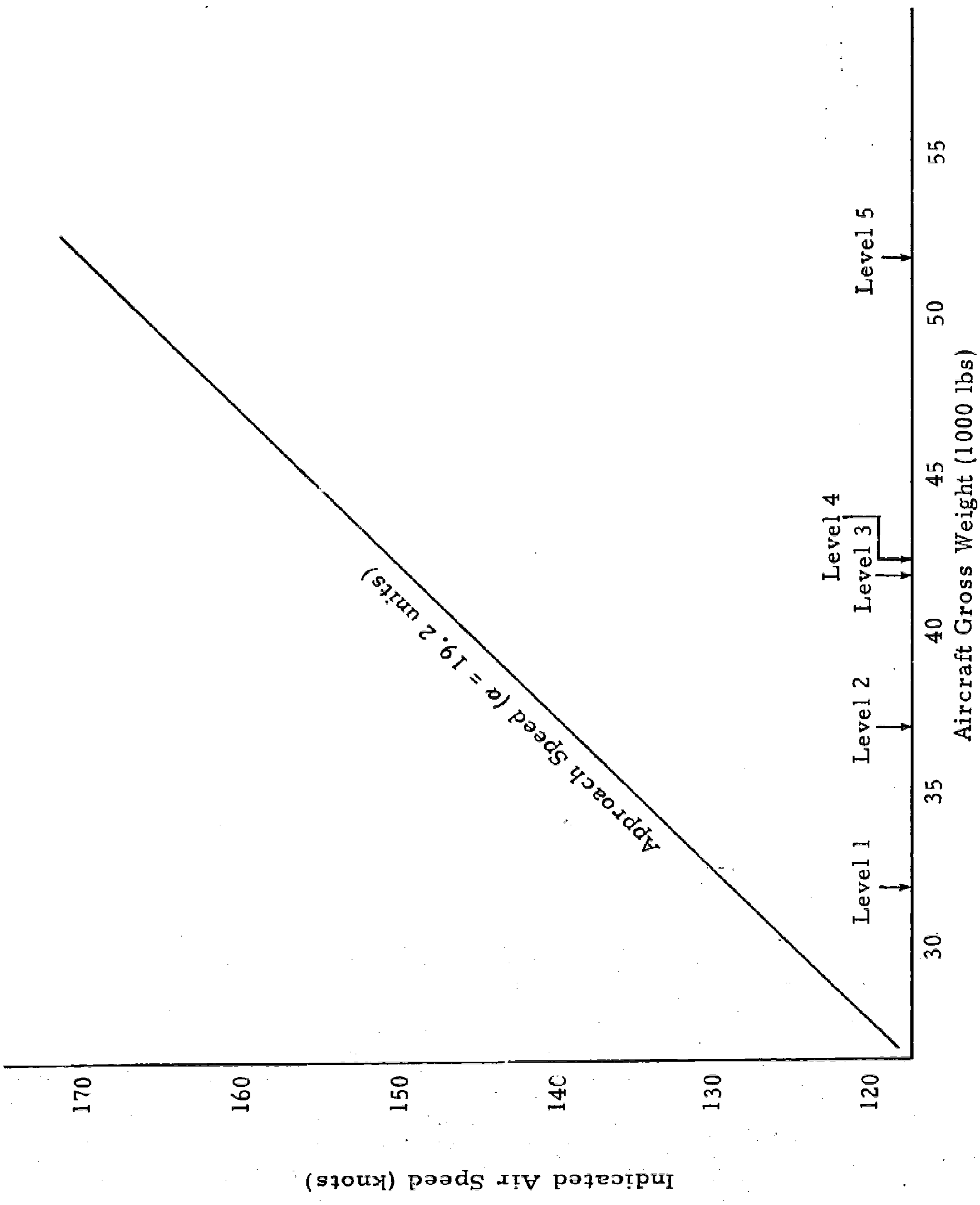


Figure 8. Approach Speed and Gross Weight

TABLE 1. GCA TRAINING COURSE

Sequence Number	Wind Level	C. G. Level	Turbulence Level
1	1	1	1
2	2	1	1
3	3	1	1
4	4	1	1
5	5	1	1
6	3	2	1
7	3	3	1
8	3	4	1
9	3	5	1
10	5	2	1
11	5	3	1
12	5	4	1
13	5	5	1
14	3	1	2
15	3	2	2
16	3	3	2
17	3	4	2
18	3	5	2
19	5	1	2
20	5	2	2
21	5	3	2
22	5	4	2
23	5	5	2
24	3	3	3
25	3	4	3
26	3	5	3
27	5	5	3
28	3	1	4
29	3	3	4
30	3	5	4
31	4	5	4
32	5	5	4
33	3	1	5
34	3	2	5
35	3	3	5
36	3	4	5
37	3	5	5
38	5	5	5

TABLE 2. EMERGENCY TRAINING COURSE

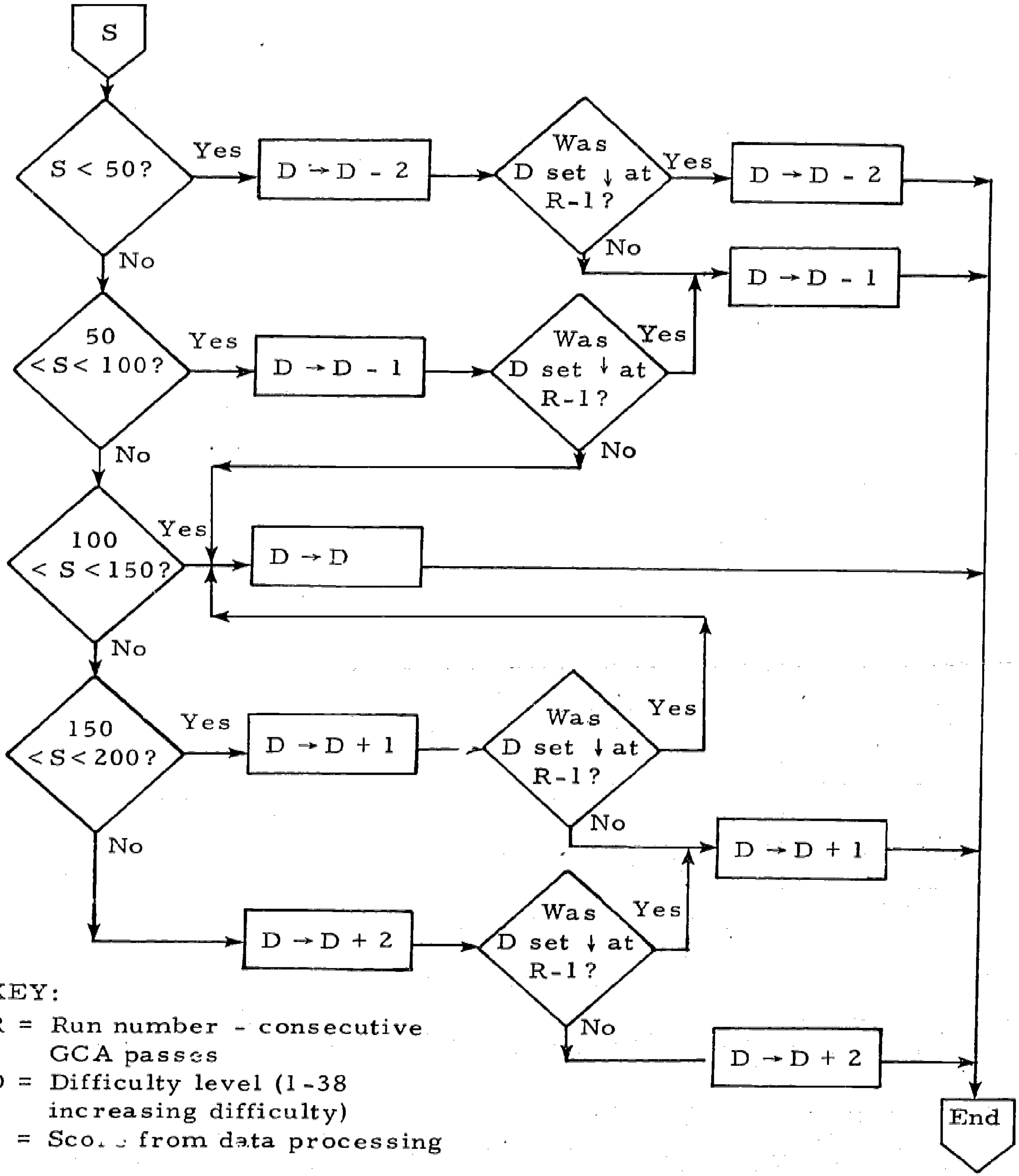
Run	Condition
1	• GCA Level - 331 • Communications Failure 4 miles from touchdown
2	• GCA Level - 332 • Communications Failure 3 miles from touchdown • Left Engine Failure 3 miles from touchdown
3	• GCA Level - 332 • Communication Failure 2 miles from touchdown • Right Engine Failure 4 miles from touchdown
4	• GCA Level - 343 • Left Engine Failure 5 miles from touchdown
5	• GCA Level - 343 • Right Engine Failure 3 miles from touchdown

number of runs was held to the minimum since the basic GCA course was long. It was anticipated that pilots would have little trouble in handling the two different emergencies selected after completing the GCA course.

3.3.2.2 Scheduling Plan. An adaptive logic program was developed to permit the student to complete the course in accordance with his ability. Figure 9 is a flow diagram of the logic developed. The procedure is actually "adaptive-adaptive" since a series of successful runs can accelerate the schedule. Table 3 summarizes the effect of the logic implemented. No adjustments were made in the expected or average scoring range. This was done to prevent any oscillation or instability at the basic level.

Emergency procedures were not adaptively scheduled.

3.3.2.3 Performance Measures. A variety of performance measurements were investigated ranging from control stick displacements and rates to vehicle angles and rates to GCA errors. As discussed earlier, interpretation becomes difficult for all but direct system performance



KEY:

R = Run number - consecutive GCA passes

D = Difficulty level (1-38 increasing difficulty)

S = Score from data processing

Figure 9. Adaptive Logic Flow Chart

TABLE 3. DIFFICULTY LEVEL INCREMENT LOGIC

Previous Run's Sequence Number Increment Status	Score < 50	$50 \leq$ Score < 100	$100 \leq$ Score < 150	$150 \leq$ Score < 200	$200 \leq$ Score
- (Decremented)	-4	-2	0	+1	+3
0 (No change)	-3	-1	0	+1	+3
+ (Incremented)	-3	-1	0	+2	+4

measures. Fortunately, the GCA has very definitive performance requirements. Therefore, measures related to operational performance were feasible. Two separate scores were developed. The first reflected performance during the run. The second reflected offset position relative to the runway at the conclusion of the control phase of the PAR.

3.3.2.3.1 Approach Path Performance. Three measures were taken during the approach beginning with handover to the PAR controller and terminating with wave-off, crash, or penetration of the final gate. The hand over to final controller involved the student establishing a fixed set of conditions. These included:

1. Wheels down, full flaps and speed brake in
2. Heading - between 040 and 050 degrees (approach course was set at 045 degrees)
3. Angle of attack - between 15.0 and 21.2 units (19.2 optimum)
4. Altitude - between 2400 and 2600 feet

Once these entry conditions were simultaneously satisfied, the runway was automatically positioned 9 miles ahead at the end of the glide slope. Thus, the runway literally floated ahead of the pilot until he established entry conditions.

Samples of position error and angle of attack were taken every second while on final. The glide slope information sampled was the location of the aircraft in terms of controller input, i.e., "on glide slope, slightly above, above, well above," etc. At the end of the run, whether by wave off or successful gate penetration, the number of samples in each GCA command level were summed for that level. The heading error sampled each second was the actual correction required at that instant, i.e., the heading correction which would have been or was issued by the PAR controller. (Samples were categorized as less than $.5^{\circ}$ error, $.5^{\circ}$ to 5° error, and greater than 5° error.) Details of the mechanization will be discussed under Software Design.

Angle of attack (α) error was sampled relative to the indexer presentation used by the pilot. These levels correspond to the following:

1.	Very fast	α (units) < 18.0
2.	Fast	$18.0 \leq \alpha$ (units) < 18.7
3.	On	$18.7 \leq \alpha$ (units) < 19.7
4.	Slow	$19.7 \leq \alpha$ (units) < 20.4
5.	Very slow	$20.4 \leq \alpha$

Thus regardless of the termination point of the run, scores of glide path, approach course and angle of attack performance reflecting information utilized by the pilot were available at a one second sample rate.

3.3.2.3.2 Successful Run Score (Gate Score). Measures reflecting actual position with respect to the glide path at the time of passing through the final "gate" were developed. Five measures were taken:

1. Lateral displacement in feet from the approach course center line.
2. Vertical displacement in feet from the glide slope center line.
3. Angle of attack error in units from optimum (19.2 units)
4. Rate of heading change in degrees per second.
5. Rate of angle of attack change in units per second.

The rate measures were included to indicate or reflect passage through the gate under marginal conditions represented by rate terms which would carry the aircraft away from touchdown point.

3.3.2.4 Scoring. The performance measures resulted in 15 path measures and five gate measures. These were combined to provide a single score for input to the adaptive scheduling plan. Figure 10 illustrates the basic logic developed for final scoring. In effect, a path score was computed for all runs. If successful, a gate score was computed and the path and gate scores were combined for a total run score. If the run terminated in a wave-off or a crash, the path score was adjusted to compensate for the proportion of the run completed.

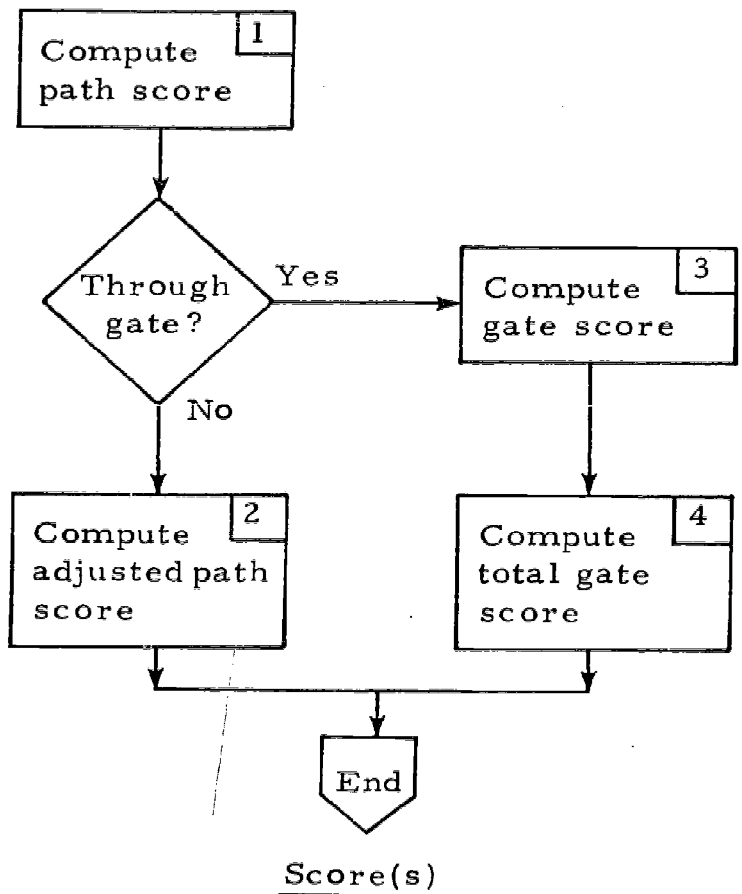


Figure 10. Scoring Logic Flow Chart

Path Score (Ps)

$$Ps = \frac{Vs + Hs + \alpha s}{3} + Ts$$

where

Ps = Path Score

Vs = Vertical (Glide Path) Score

Hs = Horizontal (Approach Course) Score

αs = Angle of Attack Score

Ts = Turbulence Score

$$Vs = \%(OGP) + \frac{\%(SAGP) + \%(SBGP)}{2}$$

where

%(OGP) = % of samples "on glide path"

%(SAGP) = % of samples "slightly above glide path"

%(SBGP) = % of samples "slightly below glide path"

$$Hs = \%(OH) + 1/2\%(HE)$$

where

%(OH) = % of samples with heading error less than .5 degrees

%(HE) = % of sample with heading error between .5 and 5 degrees

$$\alpha s = \%(\alpha)$$

where

$\%(\alpha)$ = % of angle of attack sample less than 20.3 units but greater than 18.1 units.

$$Ts = 100\ Tdf$$

where

Tdf = Turbulence Difficulty Factor (0 to .16)

The addition of the turbulence term was to offset score degradation directly attributable to turbulence effects on the score itself. For example, angle of attack variation increases with turbulence.

Adjusted Path Score (Psa)

The adjusted path score was developed to reflect the portion of the path completed prior to the wave-off or crash and compensate partially for the loss of the gate score which had an expected value of 100. The adjusted path score was computed as follows:

$$Psa = L\ (Ps + 100)$$

where

Psa = Adjusted Path Score

Ps = Path Score

L = Proportion of Glide Path Completed

Gate Score (Gs)

The gate score was computed whenever the student successfully passed through the terminal gate, i.e., did not crash or wave-off during the run. The wave-off criteria were:

1. Passing beyond the "well above (below) glide path" band.
2. Passing beyond the approach course offset error limit.

The gate score was computed as follows:

$$Gs = \frac{Ys + Zs + As - \dot{\psi}s - \dot{\alpha}s}{3}$$

where

Gs = gate score

Ys = horizontal gate score

Zs = vertical gate score

As = angle of attack error score

$\dot{\psi}s$ = heading rate score

$\dot{\alpha}s$ = angle of attack rate score

$$Ys = 100 - |Ye|$$

where

Ye = glide slope offset error in feet

$$Zs = 100 - |Ze|$$

where

Ze = approach course offset error in feet

$$As = 100 - 25(|\alpha - 19.2|)$$

where

α = angle of attack at gate

$$\dot{\psi}s = 25|\dot{\psi}|$$

where

$\dot{\psi}$ = rate of change of heading at the gate in degrees per second

$$\alpha s = 25|\dot{\alpha}|$$

where

$\dot{\alpha}$ = rate of change of angle of attack at the gate in units per second

Total Gate Score (Gst)

The path score and gate score were combined to form a single score for successful runs. It was computed as follows:

$$Gst = Ps + Gs + 100$$

For comparison purposes, a perfect path score could range between 100 (no turbulence) and 116 (maximum turbulence). The adjusted path score could range from greater than zero to less than 216 directly as a function of the proportion of the path score. The gate score could range from a negative value (large heading or angle of attack rate) to 100. The maximum total gate score was 316.

3.3.3 Software Design

The original constraints imposed on software design reflected the requirement for compatibility with the F-4 simulation program, especially in cycle time, and the TRADEC System capability in general. Since the time remaining in the computation cycle was limited, it became clear that an executive program would be essential and that a modular approach to the program would be optimum. The executive program would be required to monitor and control execution of the modules and provide the interface with the existing TRADEC software. Other functions of the executive program include:

1. Monitor inputs.
2. Direct outputs and feedback parameters.
3. Control communications between modules.
4. Transmit data between operator and program.
5. Schedule events.
6. Establish priorities.
7. Allocate memory for the modules.
8. Provide procedures for error recovery.
9. Provide timing and accounting parameters.

The basic design of the executive program involves a foreground and background mode. The advantages of this design include:

1. Program modules can be list ordered by execution priority.

2. The Executive Routines can be completely independent of the other modules.

3. Priority of any Foreground or Background (F/B) program can be simply changed by reordering the program lists.

4. Active modules can activate or deactivate any other F/B program.

5. Inactive modules can be easily bypassed.

6. New Modules can be added by simply inserting the program and a one-word linkage to the list.

7. Obsolete modules can be removed by simply removing the program module and the one-word linkage.

8. Modules can be virtually removed by deleting the one-word linkage.

9. Foreground modules can be transferred to Background (and vice versa) by interchange of the one-word linkage.

These features are obviously desirable for an advanced program where flexibility is essential. Figure 11 illustrates the basic hardware/software system flow. Figure 12 shows the structures of the executive program and the modules developed to implement the ATE System. A functional description of all the modules is contained in Appendix H.

3.3.3.1 <u>ATE Foreground Program.</u> Five foreground modules are controlled by the ATE Foreground Executive routine which provides the interface between them and the F-4 simulation program. The ATE foreground modules are:

1. ATE Glide Path Dynamics Module. - Computes X, Y, and Z coordinates and X and Y rate of the aircraft relative to the glide path and approach course. Figures 2 and 3 show the geometry involved.

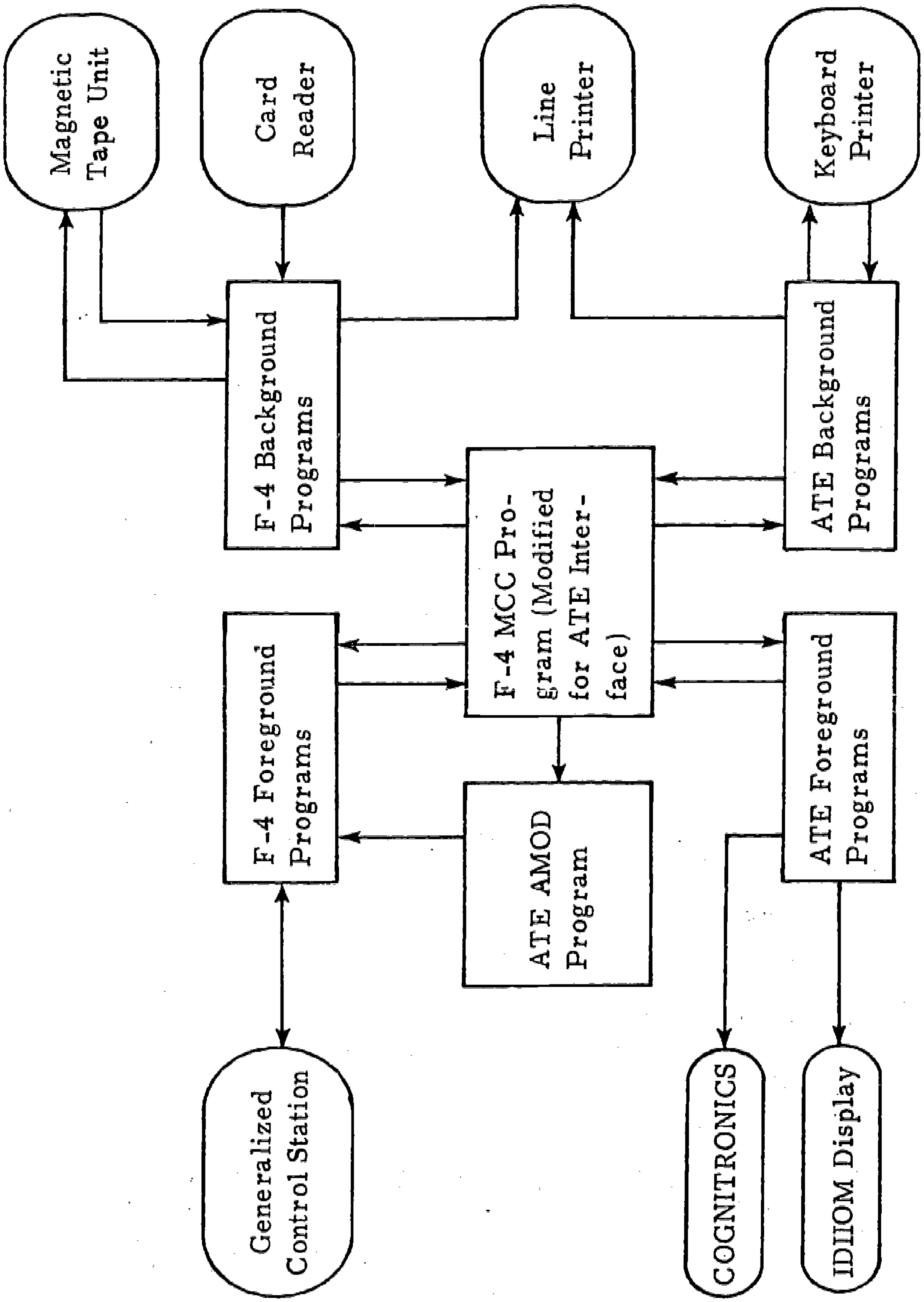


Figure 11. F-4/ATE Basic Hardware/Software System Flow

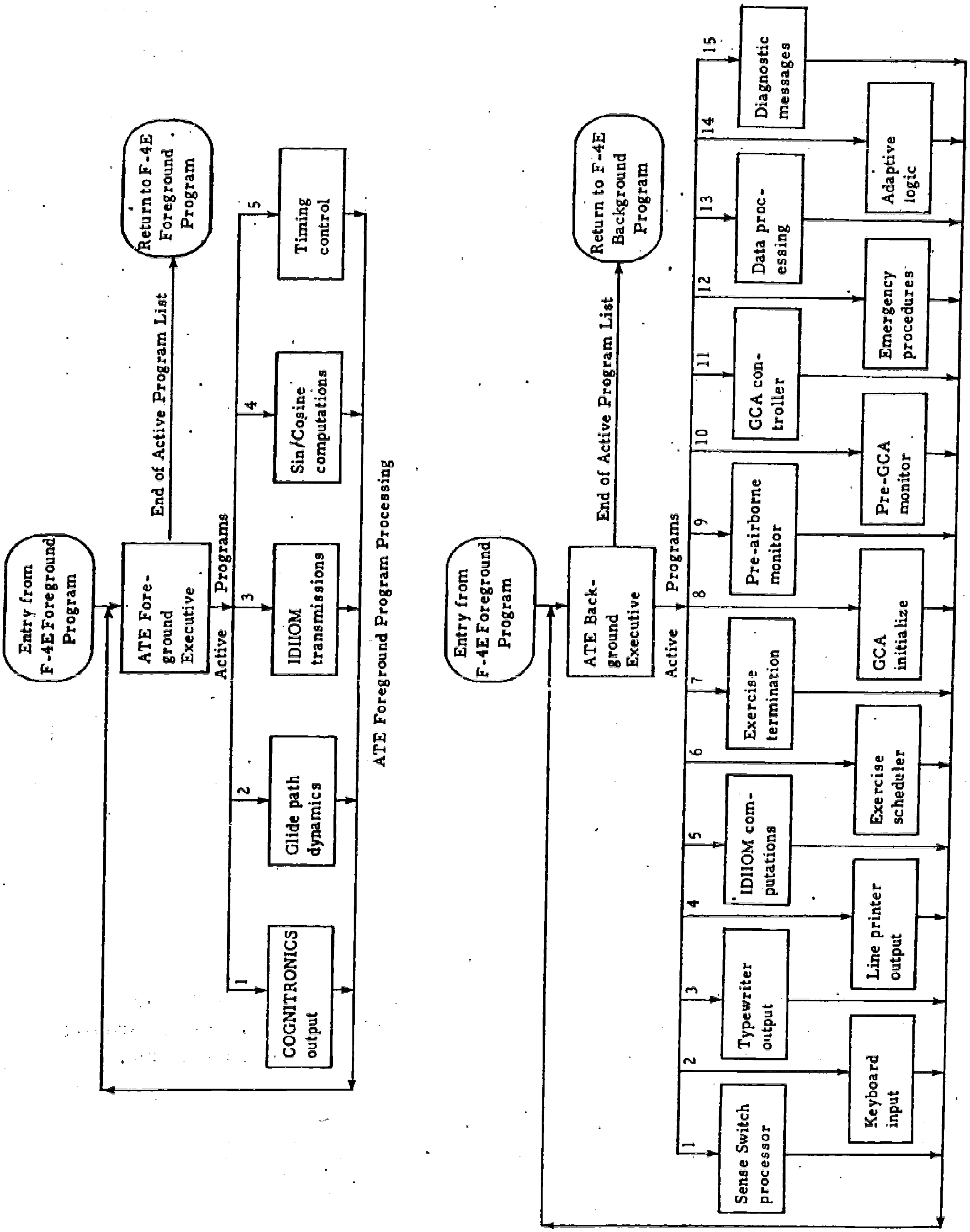


Figure 12. Basic ATE Executive Structure

2. COGNITRONICS Output. - Monitors and controls all COGNITRONICS messages. The major functions include:

   a. Select and place the next output word address in the buffer.

   b. Deactivate the routines if no message words are waiting.

   c. Manipulate the message queue to insure correct priority output.

   d. Insert new messages into the queue in priority order.

   e. Purge the queue on request.

3. IDIIOM Transmission Module. - Monitors transmission of the display list to the IDIIOM display (Note: The IDIIOM display is a graphics CRT which was used to display a plot of each run.)

4. Sine/Cosine Computation. - Computes sine and cosine for runway orientation.

5. Timing Control. - Provides ATE timing parameters.

3.3.3.2 ATE Background Program. Fifteen separate modules controlled by the ATE Background Executive routine comprise the ATE Background program. Five of the modules are self explanatory and provide basic subsystem control and readout. These are:

1. Sense Switch Processor
2. Keyboard Input
3. Typewriter Output
4. Line Printer Output
5. IDIIOM Computation

One module, the Diagnostic Message Module, was designed but not utilized during the demonstration because of the difficulty in assembling meaningful messages from the existing COGNITRONICS vocabulary.

The remaining modules comprise the body of the ATE automated training program. Functional requirements will be briefly reviewed in order of use in the exercises. More detailed descriptions are contained in Appendix H.

1. GCA Initialize - sets initial GCA parameters and switches for the next run.

2. Pre-Airborne Monitor - monitors and instructs the subject until airborne. Four phases are involved:

   a. Phase 0 - Begins with sensing engine start, directs the start of the audio briefing and selects initial difficulty factors.

   b. Phase 1 - Audio briefing phase.

   c. Phase 2 - Checks for take-off configuration and issues takeoff clearance via COGNITRONICS. The critical takeoff check items are:

      1) Landing gear down
      2) Flaps 1/2 down
      3) Engines started (flame both engines)
      4) Aircraft on ground
      5) Speed brake in

      If the configuration is not achieved in 30 seconds, the discrepancy is detected and a COGNITRONICS output is made, i.e., "CHECK TAKEOFF SETTINGS." At the same time a message is output on the typewriter identifying the problem. i.e., :

      1) "CHECK WHEELS UP"
      2) "CHECK FLAP POSITION"
      3) "CHECK SPEED BRAKE OUT"
      4) "CHECK ENGINES"
      5) "CHECK A/C ON GROUND"

      A similar output could not be provided to the student within the existing word structure. The above messages were repeated every thirty seconds until the takeoff configuration was achieved. At this point a COGNITRONICS message was sent to the student - "CLEARED FOR TAKEOFF" and also outputted on the typewriter.

d. Phase 3 - Verifies lift off. "AIRCRAFT AIRBORNE" is output on the typewriter when accomplished.

3. Pre-GCA Module - monitors student performance from lift off to hand-over to the PAR controller. Four phases are employed:

a. Phase 0 - Provides climb-out instructions.

b. Phase 1 - Primarily checks aircraft configuration for GCA. The requirements include:

1) Landing gear down
2) Flaps full down
3) Speed brake in
4) Angle of attack between 15.0 and 21.2 units
5) Altitude between 2400 and 2600 feet
6) Heading within $\pm 5^{o}$ of runway orientation

Each particular discrepancy is output on the typewriter. Each minute thereafter until the configuration is achieved, a message is output via the COGNITRONICS to "CHECK LANDING SETTINGS". The previous run, if any, displayed on the IDIIOM is reinitialized when configuration is achieved.

c. Phase 2 - GCA initialization messages sent over COGNITRONICS.

d. Phase 3 - Activates GCA programs. Once configuration is verified and initialization completed, the message "START GCA APPROACH" is output to the typewriter and the IDIIOM, timer and glide path dynamics program modules are activated.

e. Phase 4 - Activates GCA controller module.

f. Phase 5 - Reentry routine for subsequent runs.

4. GCA Controller - provides GCA instruction information for output to the pilot. This module simulates all the functions of the PAR human controller. In addition it also samples

the performance as required. The module is discussed in detail in Appendix H.

5. Emergency Procedures Processor - monitors the emergency procedures runs when implemented. The emergency is activated as scheduled and terminated as required. Three additional performance measures are collected, namely response time to the communication failure, and throttle and flap response time for the engine failures.

6. Data Processing Module - processes and outputs the performance data and scores to the high speed printer. Figure 13 is a sample of the format for performance data output for each GCA.

7. Adaptive Logic Module - selects and implements the difficulty levels for the next run in accordance with the adaptive logic discussed earlier.

8. Exercise Termination - monitors the training status and terminates the session (with landing instructions) if the session is completed or issues climb-out instruction for another run. The module also provides for engine re-start on single engine failure emergency runs and initialization of program routing parameters.

In summary, the major portion of the ATE Program is contained in the ATE background mode. It consists of input/output modules, interface formatting modules, and the basic GCA program modules. The latter includes simulation of the air traffic control functions, PAR functions, and instructor functions. In addition, the syllabus control is handled with an adaptive approach and the scoring is completed for each run. Detailed descriptions of the modules are contained in Appendix H.

3. 3. 4 System Implementation and Debug

The implementation of the ATE program and debugging was relatively routine. No unusual problems were encountered.

```
NAME    XXXXXXXX    DATE    XX/XX/XX

    RUN NUMBER  XXXX     EXERCISE  XXXX    LEVEL   XXXX    SESSION XXXX.

    GLIDE PATH VARIANCE DATA    TOTAL NUMBER OF SAMPLES     XXXX

      VERTICAL            WELL ABOVE    ABOVE    SLGT ABOVE     ON      SLGT BELOW     BELOW    WELL BELOW

        SAMPLE SIZE        XXXX.XXX    XXXX.XX    XXXX.XXX   XXXX.XXX   XXXX.XXX    XXXX.XXX   XXXX.XXX

        PERCENT OF TOTAL   XXXX.XXX    XXXX.XXX   XXXX.XXX   XXXX.XXX   XXXX.XXX    XXXX.XXX   XXXX.XXX

      HORIZONTAL                    HC < 0.5 DEG         0.5 DEG<HC < 5 DEG        HC > 5 DEG

        SAMPLE SIZE                  XXXX.XXX              XXXX.XXX                XXXX.XXX

        PERCENT OF TOTAL             XXXX.XXX              XXXX.XXX                XXXX.XXX

      NO GLIDE PATH VARIANCE DATA THIS RUN

      TOTAL NUMBER OF RUNS THIS FILE  XXXX

      RUN TERMINATED BY      XXXXXXXXXXXX

      ANGLE OF ATTACK      VERY FAST     FAST      ON SPEED      SLOW     VERY SLOW

                            (0-18)   (18.1-18.6) (18.7-19.6) (19.7-20.3)  (20.4-30)

        SAMPLE SIZE        XXXX.XXX    XXXX.XXX   XXXX.XXX   XXXX.XXX   XXXX.XXX

        PERCENT OF TOTA    XXXX.XXX    XXXX.XXX   XXXX.XXX   XXXX.XXX   XXXX.XXX

    PATH DATA      % OF PATH COMPLETED  XXX.XXX          TIME (SECONDS)  XXXX.XXX

    GATE DATA

                   LATERAL ERROR (Y)   XXXX.XXX (XXXXX) FEET   HEADING RATE OF CHANGE  XXXX.XXX DEG/SEC

                   VERTICAL ERROR (Z)  XXXX.XXX (XXXX)  FEET   AOA RATE OF CHANGE      XXXX.XXX UNITS/SEC

                   AOA ERROR (A)       XXXX.XXX (XXXX) UNITS

    SUMMARY        PATH SCORE      XXXX.XXX         ADJUSTED PATH SCORE XXXX.XXX

                   GATE SCORE      XXXX.XXX         TOTAL GATE SCORE    XXXX.XXX

    EMERGENCY DATA     THROTTLE RESPONSE (SECONDS) XXXX.XXX       FLAP RESPONSE (SECONDS) XXXX.XXX

                       COMMUNICATIONS FAILURE RESPONSE (SECONDS)    XXXX.XXX

    * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

                                                  X's INDICATE DATA TO BE SUPPLIED BY THE PROGRAM
```

Figure 13. Data Output Format

3.4 TEST OF SYSTEM

F-4 pilots as well as experienced simulator operators were utilized for verification of initial parameters settings. Difficulty level, scoring routines, briefings, debriefings, etc. were checked. The combination of modular programs under a F/B executive program with a systems approach resulted in only minor adjustments to the design values. The changes invloved the following values:

1. Turbulence Setting. The initial values selected for turbulence were based on an earlier study conducted on the TRADEC which involved subsonic to supersonic speeds. Although objective settings of the turbulence factor proved beyond the scope of this project, it was clear that the settings utilized were "representative," taxed the pilots, and regardless of the direct relation to operational turbulence, served the purpose of providing a realistic difficulty factor.

2. Course Difficulty Sequence. Again, incremental increase in difficulty for each subsequent run in the course could not be established. However, the subjective opinion of the initial F-4 pilots verified that the sequence was "reasonable" and in fact, appeared to increase in difficulty. None of the test runs portrayed any oscillation at any level.

3. Scoring Procedure. The trial runs served to validate the concept of path and gate scoring. The adaptive logic based on the score levels anticipated proved to be successful.

In summary, no major changes were required as a result of the test and debug runs. Several "nonpilots" and novice pilots flew the program during this period. The automation appeared to be effective and no changes were implemented as a result of test runs.

SECTION IV

RESULTS

4.0 GENERAL

A total of 12 navy and air force F-4 pilots were "trained" during the test phase. Additional data on two nonpilots was accumulated for comparison. All of the 12 F-4 pilots were on operational flight status with an F-4 squadron.

The original training plan required a minimum of two days of training involving two sessions per day, each session consisting of 10 runs or 45 minutes whichever was less. Unfortunately, the F-4 pilots were only available for one day because of operational and training commitments. Therefore, the training plan was modified to a "pilot-demand" schedule in which the pilots flew GCA runs until they were tired or wanted to rest. Two pilots were scheduled per day so that they could alternate flying and resting. Training began about 0900 and continued as late as the pilots were willing to fly or until they completed the course. The median number of trials per session was seven.

Of 51 sessions flown, only 7 contained 10 runs, and only 5 contained 9 runs. Table 4 summarizes this data. (Ten is the maximum number of runs since the training program directed a full stop landing after 10 runs.)

Statistical analysis of the data will be minimal since a rigorous experimental plan was neither planned nor conducted. As discussed earlier, the economical demonstration of technical feasibility does not typically include design or development directed to scientific experiment or hypothesis testing. In addition, modifications incorporated to accommodate student pilot availability further restricted meaningful statistical analysis of the data. However, as discussed earlier, the importance of utilizing operational personnel for demonstration purposes was considered to outweigh any shortcomings in experimental design.

System availability was excellent for the period involved. In no case was time or data lost because of equipment failure. This type of performance is considered reasonable for modern digital systems and

TABLE 4. NUMBER OF RUNS PER SESSION

Number of Runs/Session	Number of Cases
10	7
9	5
8	12
7	9
6	8
5	2
4	6
3	1
2	1*
	51

*Terminating run

should be expected in future automated trainers with reasonable system design and maintenance.

The results of the GCA and the Emergency Procedures training will be presented separately.

4.1 GCA TRAINING

The GCA training course consisted of a maximum of 38 different runs of increasing difficulty in terms of runway conditions, aircraft and drag, and atmospheric turbulence. The actual course structure for each student was developed on-line as a function of his performance in accordance with the adaptive logic program discussed in Section 3. The results of this program can be seen in Table 5, which summarizes the runs and sessions data for the 12 pilots.

As can be seen, 5 of the 12 pilots completed the GCA course in the sense of reaching the most difficult level of the syllabus. The median number of runs for these pilots was 26 as opposed to a median of 30 for the pilots who did not complete the course because of time limitations or fatigue.

Plots of the progress of each pilot as a function of the run number and difficulty level reached were made and are contained in Appendix I.

Table 6 summarizes the wave-off data from these runs.

TABLE 5. GCA TRAINING RUNS BY PILOT

	Pilot												
	1	2	3	4	5	6	7	8	9	10	11	12	Mdn
Number of runs	26	13	26	30	34	19	33	42	34	27	25	26	28.5
Maximum level achieved	33	38*	38*	33	25	38*	38*	18	34	38*	30	24	33.5
Number of sessions	4	3	5	4	5	3	5	5	5	4	4	4	4
Average runs per session	6.5	6.3	6.4	7.5	6.8	8.0	7.4	8.4	6.8	8.0	6.2	6.5	7

*Level 38 represents maximum difficulty and final course run.

TABLE 6. NUMBER OF WAVE-OFFS BY PILOT

	Pilot												
	1	2	3	4	5	6	7	8	9	10	11	12	Total
Number of wave-offs	9	0	7	15	18	5	15	20	8	5	11	16	129
-glide slope limits	4	-	3	12	15	3	14	15	7	3	7	8	91
-course limits	5	-	4	3	3	2	1	5	1	2	4	8	38

The final scores for each run were grouped into blocks of five. This data is presented in Tables 7 and 8.

Table 9 summaries the results of the adaptive logic program. It lists the frequencies of the different level changes possible and the average changes from run to run for each pilot.

4.2 EMERGENCIES

Only 5 of the 12 pilots reached the emergency level of course difficulty. Of these, only 3 completed all 5 emergency runs, the other two completed 3 and 4 of the emergency runs. Response times were recorded. The instructions for communication failure were to execute a missed approach procedure if communication was lost for 5 seconds. The response time started with the communication loss and terminated when the pilot reached the assigned altitude and completed 180° of the holding pattern. The flaps and throttle response time started at engine failure and terminated when the flaps had been retracted to one-half and when the throttle on the good engine had been advanced.

4.2.1 Emergency Run 1

The first emergency involved a communications failure at four miles from touchdown. All five pilots who flew the run successfully completed it; i.e., executed a missed approach. The mean response time was 106.3 seconds ($\sigma = 14.0$ seconds).

4.2.2 Emergency Run 2

The second emergency involved a combined engine failure and communication failure at three miles from touchdown. All five pilots who flew the run successfully completed it and executed missed approaches. The mean response time for the missed approach was 126.5 seconds ($\sigma = 32.8$). The mean response time for throttle and flaps was respectively, 2.3 seconds ($\sigma = 1.3$ seconds) and 4.6 seconds ($\sigma = 1.3$ seconds).

4.2.3 Emergency Run 3

The third emergency involved an engine failure at four miles and a communication failure at two miles. The correct response was to continue the GCA on single engine until the communication failure occurred. Five pilots completed the run but all took wave-offs before the communication failure occurred. All of the wave-offs were because

TABLE 7. AVERAGE RUN SCORES BY PILOT (BLOCKS OF 5 RUNS)

Runs	1	2*	3*	4	5	6*	7*	8	9	10*	11	12
1- 5	154.9	202.2	127.6	174.4	88.5	172.2	145.2	136.5	172.6	152.5	122.5	137.3
6-10	193.7	197.8	176.4	156.8	136.1	151.6	168.7	150.8	149.6	170.8	172.5	155.6
11-15	170.7	207.0	171.3	200.3	128.7	185.5	166.1	139.4	148.0	186.8	174.3	183.3
16-20	164.3	-	189.2	182.6	156.6	191.3	149.7	151.3	158.5	166.0	175.5	161.9
21-25	158.5	-	190.2	103.6	146.2	-	169.3	151.2	156.0	167.5	133.4	142.1
26-30	-	-	-	139.2	176.5	-	159.9	145.0	152.3	-	-	-
31-35	-	-	-	-	133.5	-	191.2	139.1	130.3	-	-	-
36-40	-	-	-	-	-	-	-	150.0	-	-	-	-
41-45	-	-	-	-	-	-	-	168.8	-	-	-	-
Average	168.6	202.3	169.1	159.5	138.0	175.1	164.3	145.4	152.7	168.7	155.6	156.0

*Completed course.

TABLE 8. AVERAGE FINAL SCORES BY BLOCKS OF RUNS

Runs	Completed Course	Did Not Complete
1 - 5	159.9	140.7
6 - 10	173.1	157.4
11 - 15	183.1	163.5
16 - 20	174.0	164.3
21 - 25	175.7	141.6
26 - 30	-	153.3
31 - 35	-	134.3
36 - 40	-	150.0
41 - 42	-	168.8

of course errors. Mean throttle response time was 2.0 seconds (σ = 0.24 seconds). Mean flap response time was 5.0 seconds (σ = 2.1 seconds). One pilot did not raise flaps to one-half for the missed approach.

4.2.4 Emergency Run 4

The fourth emergency involved an engine failure at five miles under conditions of level three turbulence and level four weight. Four pilots attempted the run, but all took wave-offs, two for glide slope errors, and two for course errors. Mean throttle response was 2.2 seconds (σ = 0.58 seconds). Flap response time was 2.3, 5.2, 4.7, and 46.8 seconds.

4.2.5 Emergency Run 5

The fifth emergency involved an engine failure at three miles under level three turbulence and level four weight. All three of the pilots who attempted the run took wave-offs for course errors. Mean throttle response was 1.7 seconds (σ = 0.13 seconds) and mean flap response was 4.3 seconds (σ = 0.5 seconds).

Table 10 summarizes the response time data for the emergency runs.

TABLE 9. ADAPTIVE LOGIC RESULTS BY PILOT

Number of Levels Changed	1	2*	3*	4	5	6*	7*	8	9	10*	11	12	Total
No change	10	-	8	12	19	2	12	29	12	6	9	13	132
Advanced 1 level	5	-	5	4	5	3	6	7	8	6	2	4	55
Advanced 2 levels	8	5	8	8	5	4	12	4	11	12	7	3	87
Advanced 3 levels	1	1	-	-	-	-	1	-	1	-	4	2	10
Advanced 4 levels	1	6	4	4	2	7	1	-	-	2	1	2	30
Retreated 1 level	-	-	-	-	2	1	-	1	1	-	-	1	5
Retreated 2 levels	-	-	-	1	-	1	-	-	-	-	-	-	2
Retreated 3 levels	-	-	-	-	-	-	-	-	-	-	1	-	1
Average change/ run	1.1	3.1	1.5	1.1	.6	2.2	1.2	.3	1.0	1.5	1.2	1.0	1.1

*Completed course.

TABLE 10. EMERGENCY RUN RESPONSE TIMES (SECONDS)

Type of Emergency	Cases	Mean	Standard Deviation
Communication failure alone	5	106.3	14.0
Communication failure with engine failure	5	138.8	23.7
Throttle response (engine failure)	17	2.1	.5
Flap response (engine failure)	15	4.7	1.5

4.3 OTHER STUDENTS

Data on two other students was collected. One was an ex-military pilot who had some experience with the simulator but had never flown the F-4 aircraft. The second student was the technician utilized in the debugging of the program. He had considerable experience with operational F-4 trainers and, of course, considerable experience with the TRADEC before the test runs were made. The technician completed the course in 13 runs taking only two wave-offs. He advanced an average of 3.2 steps per run. The non F-4 pilot reached level 32 in 19 runs with an average advance of 1.8 steps per run. Plots of the runs are contained in Appendix I.

The technician also completed the emergency runs which are summarized in Table 11.

These runs (Table 11) also represent the only successful run for the third and fourth emergencies during the test. None of the students were successful on run number 5 (engine failure near minimums).

TABLE 11. TECHNICIAN EMERGENCY RUN RESULTS

Type of Emergency	Termination	Response Times (Seconds)		
		Throttle	Flaps	Missed Approach
1-Communication failure	successful	NA	NA	50.5
2-Engine and communication failure	successful	1.3	8.5	77.5
3-Engine and communication failure	successful	1.2	3.9	77.6
4-Engine failure	successful	1.6	4.6	NA
5-Engine failure	glide slope wave-off	1.2	4.2	NA

4.4 QUESTIONNAIRE RESULTS

Responses to the questionnaire (Appendix D), by the F-4 pilots, were tabulated and the detailed results are contained in Appendix J. The questionnaire covered three general aspects.

1. Comments on the simulator

2. Comments on the GCA simulation and training

3. Pilot experience

4.4.1 Comments On The Simulator

In general, the simulator was considered well designed and characteristic of the F-4 aircraft except that pitch response and pitch trim appeared to be too sensitive.

4.4.2 Comments on the GCA Simulation and Training

In general, the GCA training program and simulation were very well received with almost all aspects rated as good to very good. It was interesting to find that the quality of the voice transmission (COGNITRONICS) was considered good and the frequency was "about right." Although the glide slope and course information was rated as satisfactory, comments were made concerning the need for rate information (which could not be incorporated in this test). Of particular interest for the future were the comments on the training course structure. There was unanimous agreement that the course difficulty levels were about right and increased consistently. All agreed that the wind effects and the weight and drag changes were about right and occurred in the proper sequence. Although most (two-thirds) considered the turbulence as about right, the remainder felt the turbulence was too severe for GCA. Both the communication and engine failure were rated as "real" and representative of actual occurrences.

4.4.3 Pilot Experience

All of the F-4 pilots were current and indicated that they had flown the F-4 aircraft within the last month and with two exceptions, had flown a GCA in the F-4 in the last month. The median experience level (jet hours) was about 900 hours and ranged from 770 hours to 4,700 hours. All had flown at least 50 hours in the last six months. F-4 experience averaged about 700 hours and ranged from 50 hours to 1800 hours.

SECTION V

DISCUSSION

5.0 GENERAL

With minor exceptions, the approach taken to demonstration of technical feasibility of automated training proved highly successful. The major key to the success lay in the modular approach to the program structure and the foreground-background executive routine design. Although most of the values initially chosen for constraints and other governing parameters proved correct, the modular approach using tabled values permitted easy change of values which were not optimum. Above all, it proved to have the flexibility required for general purpose training. The entire course could be altered without rewriting the program. The basic structure could be utilized for many courses on the same trainer which in the future could also be updated and modified by training personnel with very little programming experience.

Positive computer control of the training course proved a much simpler task than had been originally perceived. The preliminary analysis had shown several "cul-de-sacs" existed which unless carefully controlled, could permit the student to literally exit the program with little possibility of automatic recapture or control. However, as the analyses continued, solutions were found and the number of such possibilities turned out to be very limited. Again the benefit of detailed task and system analysis proved itself. The end result was that not a single case of manual override by the system operator was required during the training.

The "simulated" automatic functions which were performed by the system operator are all readily automatized in a final system. As will be recalled, these functions included the following:

1. Typewriter input of the students name (could be done by the student).

2. Activation of the tape recorder.

3. Activation of the motion platform and the reset function.

The latter two are simple discrete switch functions.

Overall, the motion platform and cockpit proved satisfactory for the tests and were very well received by the pilots. Limitations of the cockpit instrumentation were obvious to the pilots but did not appear to affect their flying. Comments on the compass were most common (moving needle vice moving card), but again no complaints or statements that it affected their flying were made. Trim sensitivity and vertical stability were also mentioned. Again, no comments on effects on performance were made. The instrumentation and stability inadequacies would be relatively easily corrected in an operational flight trainer.

5.1 AUTOMATED TRAINING

With the exception of the schedule, the original training plan proved effective. Again, the modular approach to programming provided the flexibility to change the course and schedule where required. The difficulty factors and the sequence of the trials proved effective. All of the pilots indicated that the sequence appeared to be correct, i.e., increasing in difficulty and that the levels of the factors was meaningful. The turbulence settings could be decreased although it is doubtful if greater pilot concurrence would be achieved. Training effectiveness studies could optimize these settings.

The adaptive logic routine proved satisfactory for the demonstration. The concern over possible instabilities may have been unwarranted. At any rate, training effectiveness studies should provide an evaluation of the routine. It is clear that the procedures utilized did permit rapid acceleration through the course. The data of course showed that the performance of the pilots was compatible with their progress. The relation of training performance to actual flight performance remains to be established, although if pilot opinion is valid, the training appears to have been effective. The adaptive-adaptive nature of the course was successful. There was no evidence of any instability where acceleration of the course occurred. Again, effectiveness studies will be required to verify the procedure since the assumption of equal difficulty steps is inherent in the approach taken.

The GCA course utilized in this test consisted of a longer than normal glide-slope — in this case eight miles in length with entry at 2500 feet of altitude. The longer final approach was chosen to permit a greater exercising and testing of some of the critical modules. In particular, extensive test was desired of the:

1. GCA Controller module.
2. Performance measurement module.
3. Adaptive Logic module.

The longer flight path permitted more exercise of the priority message logic, message criteria, flight path performance, and on-line course restructuring techniques. Changing the flight path to typical GCA conditions involves simple table changes. In view of the success of the above modules, no problems are foreseen in these changes. Training effectiveness studies should be done to optimize path length. It could well be that a longer path, although unrealistic, provides greater training.

The performance measurement plan utilized in the tests proved successful. Again, training effectiveness studies should be conducted to verify the relative weighting of the various performance components involved. While the analyses completed indicate that the scoring technique is effective and appears to be objective, it could be that increased weight should be given to final conditions, i.e., final gate performance. However, regardless of the relation of the performance measures to the ultimate criteria, it is clear that the measures are effective in governing the training course. It may be, that further refinement of the measures are not required if the effectiveness of the training can be verified. In other words, a pragmatic approach to performance measurement can be taken.

5.2 MISCELLANEOUS

The computer controlled voice system was well received although the obvious problem of vocabulary deficiencies existed. This can be rectified easily in an operational trainer. The "rigid" inflection pattern which originally had been assumed to be objectionable, proved the opposite. The fixed pattern appeared to produce an objectivity in the GCA instructions which may not exist in human GCA controllers. The COGNITRONICS messages never reflected concern or alarm. Most of the pilots appeared to prefer this rigidity since it simplified their interpretation of the commands.

The need for trend information in the instruction set was noted by most of the pilots. Again, this is easily implemented and requires only the appropriate vocabulary for the instructions.

Heading command logic should be reviewed. The asymptotic approach based on half the remaining distance presented no problems in the tests conducted. However, some of the pilots indicated a preference for more rapid return to the approach course. The logic used in these tests appears to be close to that actually used by GCA controllers.

It might be that the addition of trend instructions would resolve the objections posed by some of the pilots.

The display of the glide slope and course position for each GCA run proved of considerable interest to the pilots as well as to all observers. Figure 14 shows the nature of the display used. Photographs of the displays were taken for some of the runs. A hard copy printout of the display appears to be desirable. Some of the pilots even indicated the desire for a repeater in the cockpit. While such a display might prove effective in providing feed-back information to the pilot after each run, an active display during the run would certainly be of questionable value in terms of GCA training.

Improvements in cockpit displays and controls are obviously desirable for operational training. In particular, the control-display ratios and responses should reflect the operational aircraft.

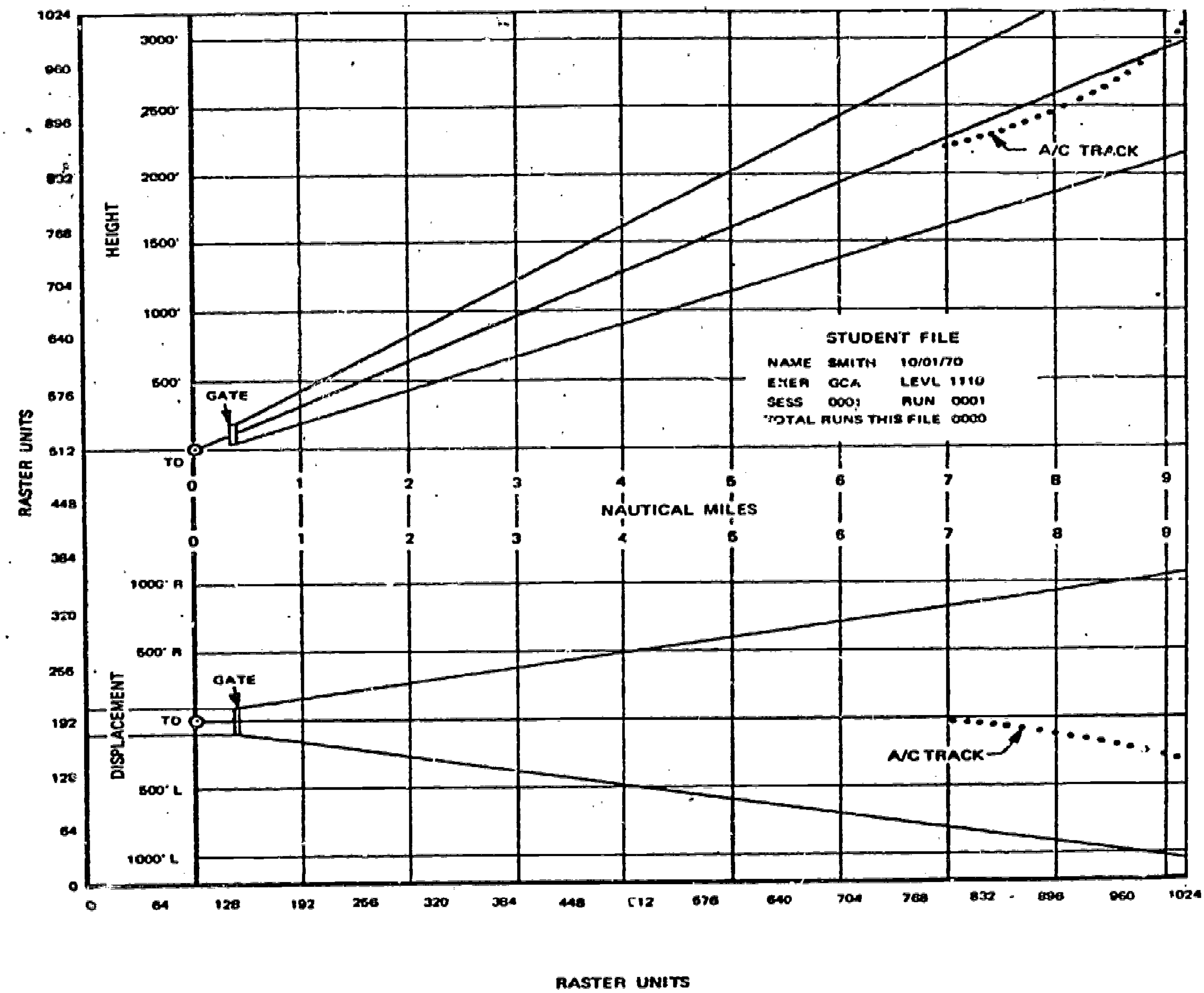


Figure 14. Diagram of GCA Display

SECTION VI

CONCLUSIONS

The technical feasibility of automated instruction in a weapons system trainer has been clearly demonstrated. The state-of-the-art of digital systems and training methodology is adequate for implementation of automated training.

Based on the limited nature of the tests conducted, the following additional conclusions are suggested:

1. Automated flight training is acceptable to pilots.

2. Adaptive training techniques are readily implemented and appear effective and acceptable by the students.

3. Voice generation techniques are adequate for simulation purposes.

4. Pragmatic solutions to student performance measurement are feasible and prove useful for training control. Total system performance criteria, however, must still be established and measured.

SECTION VII

RECOMMENDATIONS

The successful demonstration of the technical feasibility of automated training establishes the base for demonstration of effectiveness in terms of usefulness and cost. Therefore, the primary recommendation is that the effectiveness tests be conducted, and if acceptable, automated training be implemented.

The following additional recommendations reflecting the particular nature of the tests conducted are made:

1. Trend information for glide slope and course control should be incorporated in future GCA controller computer programs.

2. Priority of messages for GCA control should be reviewed especially with the addition of trend information.

3. A shorter glide path (more realistic) should be utilized if training effectiveness is unaffected.

4. A hard copy of the GCA display for each run is desirable for student feed-back and for permanent record.

5. A verification of turbulence levels for simulation is required.

6. The TRADEC cockpit should be updated in terms of display, particularly the heading display. The addition of command type displays will facilitate further automated training studies.

7. A more flexible (in terms of vocabulary) voice generation system is required for general purpose simulation devices.

GLOSSARY

ADP	Automated Data Processing
α	Angle of Attack
α_s	Angle of Attack Score
$\dot{\alpha}_s$	Angle of Attack Rate Score
A_s	Angle of Attack Error Score
AOA	Angle of Attack
ASR	Airport Surveillance Radar
ATE	Automated Trainer Evaluation
CG	Center of Gravity
CRT	Cathode Ray Tube
F/B	Foreground/Background
GCA	Ground Controlled Approach
G_s	Gate Score
G_{st}	Total Gate Score
HE	Heading Error
H_s	Approach Course Score
IP	Index of Performance
L	Proportion of path completed
NTDC	Naval Training Device Center
OGP	On Glide Path
OH	On Heading
PAR	Precision Approach Radar

P_s	Path Score
$P_{s\hat{a}}$	Adjusted Path Score
$\dot{\psi}_s$	Heading Rate Score
SAGP	Slightly Above Glide Path
SBGP	Slightly Below Glide Path
σ	Standard Deviation
T_{df}	Turbulence Difficulty Factor
T_s	Turbulence Score
TRADEC	Training Device Computer
V_s	Glide Path Score
WST	Weapon System Trainer
XDS	Xerox Data Systems
Y_e	Glide Slope Offset Error
Y_s	Horizontal Gate Score
Z_e	Approach Course Offset Error
Z_s	Vertical Gate Score

FOOTNOTES

1. Leonard, J. N., Doe, L. H., and Hofer, J. L. Automated Weapon System Trainer. Technical Report NAVTRADEVCEN 69-C-0151-1, Naval Training Device Center, Orlando, Fla., June 1970.

2. Faconti, Victor, Mortimer, Charles P. L, and Simpson, Duncan W. Automated Instruction and Performance Monitoring in Flight Simulator Training. Technical Report AFHRL - TR - 69-29, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio, February 1970.

3. Faconti, et al., op. cit., p. 362.

170

BIBLIOGRAPHY

_______. IDIIOM Technical Description. Technical Manual, Information Displays Inc., 333 North Bedford Road, Mount Kisco, New York, 1969.

_______. IDIIOM Programmer's Manual. Technical Manual IDI-1003-A, Information Displays, Inc., 333 North Medford Road, Mount Kisco, New York.

_______. Multiplex Speechmaker Operation and Maintenance Manual. Technical Manual, Cognitronics Corp., 333 Bedford Road, Mount Kisco, New York.

_______. XDS Sigma 7 Computer Reference Manual. Technical Manual 90 09 50G, Xerox Data Systems, 701 South Aviation Boulevard, El Segundo, Calif., October 1969.

_______. XDS Sigma 5/7 Symbol/Meta-Symbol Reference Manual. Technical Manual 90-09 52C, Xerox Data Systems, 701 South Aviation Boulevard, El Segundo, Calif., December 1969.

_______. XDS Sigma 5/7 Batch Processing Monitor Reference Manual. Technical Manual 90 09 54C, Xerox Data Systems, 701 South Aviation Boulevard, El Segundo, Calif., August 1969.

_______. XDS 7020 Keyboard Printer Reference Manual. Technical Manual 90 09 74, Xerox Data Systems, 701 South Aviation Boulevard, El Segundo, Calif., August 1969.

_______. XDS 1321/7322/7323 Magnetic Tape Reference Manual. Technical Manual 90 09 77, Xerox Data Systems, 701 South Aviation Boulevard, El Segundo, California.

_______. Sylvania External Interface System. Systems Technical Manual SDS 980173, Scientific Data Systems, 12150 Parklawn Drive, Rockville, Maryland, December 1968.

_______ Sylvania External Interface System - System Documentation Package. Technical Manual EWO 7AZ60, Scientific Data Systems, 12150 Parklawn Drive, Rockville, Md.

_______. Software Documentation for the Research Tool Digital Computer System Volume IIA Detailed Program Description. Technical Report NAVTRADEVCEN 67-C-0196-7, U. S. Naval Training Device Center, Orlando, Fla, January 1969, Revised September 1969.

_______. Software Documentation for the Research Tool Digital Computer System Volume I Math Model Report. Technical Report NAVTRADEVCEN 67-C-0196-7, U. S Naval Training Device Center, Orlando, Fla., June 1968, revised September 1969.

_______. Software Documentation for the Research Tool Digital Computer System Volume II Program Report. Technical Report NAVTRADEVCEN 67-C-0196-7, U. S. Naval Training Device Center, Orlando, Fla., January 1969, revised September 1969.

_______. Central Reference Manual for Research Tool Digital Computer System (RTDCS). Technical Report NAVTRADEVCEN P-3457, U. S. Naval Training Device Center, Orlando, Fla., 15 May 1969.

_______. Fighter Squadron One Twenty-One Syllabus, (Loose Leaf) Naval Air Station, Mirimar, California.

_______. Flight Manual USAF Series F-4C, F-4D, F-4E Aircraft. Air Force Technical Order T. O. IF-4C-1, HQ ASD, Wright-Patterson AFB, Ohio, 1 September 1968.

Faconti, Victor, Mortimer, Harles P. L., and Simpson, Duncan W. Automated Instruction and Performance Monitoring in Flight Simulator Training. Technical Report AFHRL TR69-29, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio, February 1970.

Hudson, Edwin M. Adaptive Training and Nonverbal Behavior Technical Report NAVTRADEVCEN 1395-1, U. S. Naval Training Device Center, Port Washington, New York, July 1964.

Kelley, Charles R Adaptive Simulation. Technical Report, Dunlap and Assoc., Santa Monica, Cal., 15 August 1966.

Kelly, Charles R., and Wargo, Michael J. Adaptive Techniques for Synthetic Flight Training Systems. Technical Report NAVTRADEVCEN 68-C-0136-1, Naval Training Device Center, Orlando, Fla., October 1968.

Leonard, J N., Doe, L. H, and Hofer, J. L. Automated Weapon System Trainer. Technical Report NAVTRADEVCEN 69-C-0151-1, Naval Training Device Center, Orlando, Fla., June 1970.

Machol, Rober E. (Ed.) System Engineering Handbook. New York: McGraw Hill, 1965.

Orr, William D. (Ed.) Conversational Computers. New York: John Wiley & Sons, 1968.

APPENDIX A

F-4/ATE PROGRAM OPERATING INSTRUCTIONS.

A. 1 START-UP PROCEDURE

a. Initial Conditions

1. SIGMA-7 computer and peripherals ON and operating normally.

2. Insure following circuit breakers at the Circuit Breaker Panel are OFF:

   a) G-Rack

   b) CMC

   c) Power Supply

3. Place SIGMA-7 computer in IDLE mode.

4. Insert F-4 Simulator Panel into Central Patchboard.

5. Turn ON following circuit breakers at the Circuit Breaker Panel:

   a) G-Rack

   b) CMC

   c) Power Supply

6. Insure all the buttons at the Monitor Console are RESET (out), except the following which should be SET (in):

   a) Fuel Lock

   b) Y Roll

   c) Y Pitch

   d) Y Yaw

b. COGNITRONICS*

1. Turn ON both switches at the COGNITRONICS Panel.

2. Adjust COGNITRONICS speaker volume control at the rear of the Monitor Console.

c. Loading the F-4/ATE Program from Magnetic Tape

1. Set all SIGMA-7 System Sense switches to Ø (zero).

2. Insure the WRITE PROTECT switches for Disc OF1 are RESET (Down position).

3. Boot F-4/ATE Program Binary Tape onto Disc OF1 (Standard SIGMA-7 Operating Procedure).

4. Load F-4/ATE Program from Disc OF1 into SIGMA-7 memory (Standard SIGMA-7 Operating Procedure).

5. Depress the RUN button on SIGMA-7 Supervisory Console (F-4/ATE Program is now running).

d. IDIIOM Display

1. Energize the IDIIOM and VARIAN 620 computer (Standard IDIIOM Procedure).

2. Load paper tape containing the GCA Glide Path/ SIGMA-7 Communications Programs (Standard IDIIOM Loading Procedure).

3. Place IDIIOM in STEP mode. RESET all IDIIOM Registers.

4. Turn ON following SIGMA-7/IDIIOM Interface Switches:

   a) POWER

   b) ON-LINE

*Trademark

5. Place ØØØØØ in P-Register (Display program starts at location ØØØØØ).

6. Depress SYSTEM RESET, then RUN Switches (Display program is now running and ready for SIGMA-7 communications).

7. Adjust THRESHOLD and INTENSITY knobs at main and remote displays for best picture.

e. F-4 Pilot Subject Preparation

1. If this is first session, present subject with ATE PRELIMINARY BRIEFING via Audio Tape prior to subject entering cockpit.

2. While briefing is being presented, depress the "RESET-TO-ZERO" button on the Monitor Console and input STUDENT FILE DATA (See section IV).

3. After ATE PRELIMINARY BRIEFING, the subject will enter the cockpit and conduct the Pre-flight Check.

4. Energize the Motion System (use Standard Procedure).

5. After subject starts the engines, a message will appear on the keyboard printer to start the GCA AUDIO BRIEFING. At this point, either the INITIAL GCA BRIEFING (1st session) or the REPEAT GCA BRIEFING (Subsequent Sessions) is presented via Audio Tape.

6. Upon completion of the Audio Briefing, release the "RESET-TO-ZERO" button on the Monitor Console. At this point the program becomes fully automatic until completion of the Exercise Session.
NOTE: If at any time it is desired to terminate the session, it may be accomplished by again depressing the "RESET-TO-ZERO" button on the Monitor Console.

A. 2 ATE EXERCISE OPERATIONS

a. The ATE program is fully automatic and operator intervention should be held to a minimum. Operator intervention, if required, may be accomplished via the controls at the Monitor Console.
NOTE: The following controls are inactive since they are overridden by the ATE program:

1. ROUGH AIR INPUT
2. FUEL INCR/DECR INPUT
3. CENTER TANK ON/OFF INPUT
4. WING TANKS ON/OFF INPUT
5. SIDEWINDER MISSILES ON/OFF INPUT
6. SPARROW MISSILES ON/OFF INPUT

A. 3 SHUT-DOWN PROCEDURE

a. Subject Egress

1. Turn motion system OFF using Standard Procedure.
2. Have subject perform Post-Flight Check.
3. When platform levels and locks, allow subject to leave cockpit.
4. If a new subject is scheduled, re-start at Section A. le (START-UP Procedure).

b. Program Shut-Down

1. Depress sense switch #1 on the SIGMA-7 Supervisory Console and allow F-4 program to "run-down".
2. After program stops, place SIGMA-7 computer in IDLE mode.

c. Generalized Control Station Shutdown

1. Depress the "I/O RESET" button on SIGMA-7 Supervisory Console.

2. Turn OFF following switches at the Circuit Breaker Panel:

   a) G-Rack Switch

   b) CMC Switch

   c) Power Supply Switch

3. Remove F4 Simulator Panel from Central Patchboard.

d. COGNITRONICS

1. Turn OFF both switches at the COGNITRONICS Panel.

e. IDIIOM Display

1. Turn down THRESHOLD and INTENSITY knobs at main and remote displays.

2. Turn OFF following SIGMA-7/IDIIOM Interface Switches:

   a) ON-LINE

   b) POWER

3. Place IDIIOM in STEP mode.

4. Follow standard IDIIOM shut-down procedure if no further IDIIOM programs are to be run.

f. Dumping the F-4/ATE Program onto Magnetic Tape

(This section can be omitted if it is not necessary to save the current STUDENT FILE DATA.)

1. Insure the WRITE PROTECT switches for Disc OF1 are RESET (Down position).

2. Boot the "MEMORY TO DISC DUMP" program from the Card Reader (Standard SIGMA-7 Operating Procedure).

3. When the F-4/ATE program has been placed on disc OF1, the keyboard printer will respond with the following message:

YOUR JUNK IS ON THE RAD

4. Boot the "DISC TO TAPE DUMP" program from the card reader (Standard SIGMA-7 Operating Procedure).

5. Mount a magnetic tape to save the F-4/ATE program (Standard Magnetic Tape Loading Procedure):

   a) Select Tape Unit Ø (zero).

   b) Depress the RESET button on the magnetic tape unit.

   c) Depress the START button on the magnetic tape unit.

6. When the keyboard lamp illuminates, type the following:

   #7204, DCOF1, CO, RA_1^n

   The F-4/ATE program will now be written on the magnetic tape.

7. After the program has been dumped, dismount the magnetic tape and save for future F-4/ATE exercises.

A.4 STUDENT FILE INPUT PROCEDURES

a. Student name entry: $FILE (NAME)$_1^n$ Normal order of input can only be accomplished when the "RESET-TO-ZERO" button on the Monitor Console is depressed. Anytime this button is depressed, the keyboard printer responds with:

   INPUT STUDENT FILE DATA

NAME can be up to eight characters. Blanks are ignored. Up to twenty files can be maintained. ($^{n}_{1}$ in all examples indicates "new line" key.)

If a new file (name not already in file), the exercise is automatically set to the first exercise, lowest difficulty level (GCA Level 111). The session number and run number are set to 1; and the total number of runs for this file is set to ∅.

Example:

Keyboard Input:

$FILE HUNTLEY$^{n}_{1}$

(NOTE: Before any keyboard input can be made, the lamp on the keyboard must be illuminated. This is accomplished by depressing the INTERRUPT button on the SIGMA-7 System Console.)

Typewriter Response:

NEW FILE

NAME	HUNTLEY	DATE	/ /
EXER	GCA	LEVEL	1110
SESS	0001	RUN	0001
TOTAL RUNS THIS FILE			0000

If an old file (name already in file), the date, exercise, level session number, run number, and total runs are retrieved from the file and printed each time an existing file is requested. The session number is automatically incremented by 1. Run number indicates the next run for this session and is reset to 1 each time the session number is advanced.

Example:

Keyboard Input:

$FILE HUNTLEY $^{n}_{1}$

Typewriter Response:

OLD FILE

NAME	HUNTLEY	DATE	10/01/70
EXER	GCA	LEVEL	3340
SESS	0002	RUN	0001
TOTAL RUNS THIS FILE			0004

b. Date Entry: $DATE XX/XX/XX$^n_1$ The date may be inserted or updated by this command. Input is constrained to a rigid format in that two numbers separated by a slash (/) must be supplied for the month, day and year.

Example: October 1, 1970

Keyboard Input:

$DATE 10/01/70$^n_1$

Typewriter Response:

NAME	HUNTLEY	DATE	10/01/70
EXER	GCA	LEVEL	1110
SESS	0001	RUN	0001
TOTAL RUNS THIS FILE			0000

c. The file may be interrogated as follows: $^n_1$ Only the current file may be interrogated with the $ command.

Example:

Keyboard Input:

$^n_1$

Typewriter Response:

NAME	JOHNSON	DATE	10/01/70
EXER	GCA	LEVEL	1110
SESS	0001	RUN	0003
TOTAL RUNS THIS FILE			0000

d. Exercise control override: $\$EXER\ GCA = WCT_1^n$

or

$\$EXER\ EMR = EDCL_1^n$

The exercise and difficulty level set by the Adaptive Logic Program can be overwritten by this command.

GCA or EMR are the three letter exercise designators (currently GCA for the GCA exercises and EMR for the emergency procedure exercise) and WCT or EDCL the various difficulty level numeral indices.

Current Difficulty level indices are:

GCA Exercise

1.	W	indicates wind speed along the runway
	W=1	30 knot head wind
	W=2	15 knot head wind
	W=3	2 knot head wind
	W=4	15 knot tail wind
	W=5	30 knot tail wind
2.	C	indicates center of gravity parameters
	C=1	Light aircraft
	C=2	Center tank attached
	C=3	Center tank, Wing tanks attached
	C=4	Center tank, Wing tanks, Sidewinder missiles attached
	C=5	Center tank, Wing tanks, Sidewinder and Sparrow missiles attached.
3.	T	indicates turbulence factor
	T=1	No turbulence
	T=2	Very light turbulence
	T=3	Light turbulence
	T=4	Moderate turbulence
	T=5	Severe turbulence

EMR Exercise

1.	E	indicates engine failure emergency
	E=0	No engine failure this run
	E≠0	Miles from touchdown at which engine failure is to occur
2.	D	is the engine designator for engine failure emergency
	D=0	Left engine is to flame out
	D=1	Right engine is to flame out
3.	C	indicates communications failure emergency
	C=0	No communication failure this run
	C≠0	Miles from touchdown at which communications failure is to occur.
4.	L	is the table value of GCA Difficulty Levels to be employed on this run (see GCA Difficulty Level indices above)
	L=1	GCA Level 331
	L=2	GCA Level 332
	L=3	GCA Level 332
	L=4	GCA Level 343
	L=5	GCA Level 343

Example:

Keyboard Input:

$EXER GCA = 355_1^n .

Typewriter Response:

NAME	HUNTLEY	DATE	10/01/70
EXER	GCA	LEVEL	355
SESS	0001	RUN	0001
TOTAL RUNS THIS FILE			0000

If the level entered through the keyboard is in the standard Adaptive Logic Table, the adaptive logic proceeds from this point on subsequent runs. If the level is not in the standard Adaptive Logic Table, the current run will employ the input level, but subsequent runs would start at the lowest adaptive logic level (1111).

e. Run Change: $RNUM N_1^n The current run number may be changed by this command.

Example:

Keyboard Input:

$RNUM 1_1^n

Typewriter Response:

NAME	HUNTLEY	DATE	10/01/70
EXER	GCA	LEVEL	345
SESS	0001	RUN	0001
TOTAL RUNS THIS FILE			0000

f. Delete Name: $DELE $(NAME)_1^n$ Deletes the file indicated by "NAME" and reinitializes it for future use by new students (normally delete is used after the student has completed the curriculum)

Example:

Keyboard Input:

$DELE $HUNTLEY_1^n$

Typewriter Response:

FOLLOWING FILE DELETED:

NAME	HUNTLEY	DATE	10/01/70
EXER	EMR	LEVEL	3105
SESS	0004	RUN	0005
TOTAL RUNS THIS FILE			0018

g. Start Exercise: $$GO_1^n$ This is a mandatory command used to start the indicated session after all the necessary STUDENT FILE DATA has been input. No further STUDENT FILE DATA will be accepted until the "RESET-TO-ZERO" button is again depressed.

Example:

$\$GO_1^n$

Typewriter Response:

START EXERCISE

A. 5 EXERCISE PARAMETER CHANGES

Currently the following ATE program exercise parameters for any particular run may be changed, if desired.

a. Runway Orientation

b. Wind Along Runway

All exercise Parameter Changes are preceeded with the character, * (asterisk).

a. Runway Orientation

The runway orientation for successive runs may be changed by the *RUN keyboard input command. This command has the following format:

$*RUN = NNN_1^n$

where: NNN is the desired new runway orientation ranging from Ø - 360°.

Example:

$*RUN = 130_1^n$

changes the runway orientation to 130° (Runway 13) for successive GCA runs.

All other program parameters pertinent to runway orientation (wind messages, runway messages, etc.) will be altered to conform to the new runway orientation.

b. Wind Along Runway

Wind velocity parallel to the runway orientation may be altered for the next run only by this command. Wind velocity for successive runs will be determined by the Adaptive Logic in the ATE program. This command has the following format:

$$*WND = VVV_1^n$$

where: VVV is the desired new wind along Runway ranging from -50 to 100 kts. A negative value indicates a tail wind while a positive value indicates a head wind.

Example:

$$*WND = -40_1^n$$

The above input would introduce a 40 knot tail wind for the GCA run. If the runway orientation was 130°; the new wind would be 310°, 40 knots.

A. 6 ABSOLUTE PROGRAM PATCHES

These two commands allow the printing or modification of any memory location in the F-4/ATE program. They should be used, therefore, with caution so that inadvertent program anomalies are not introduced. Absolute Program Patch commands are identified by the character, + (plus)

a. Memory Location Printing

One memory location may be typed out using the following format:

$$+PRT\ LLLL_1^n$$

where: LLLL is a 4 digit hexadecimal memory location. Leading zeros must be included for memory locations less than 4 digits. The typewriter will respond with the 8 digit hexadecimal contents of location LLLL.

Example:

Keyboard Input:

+PRT 03F9$^{n}_{1}$

Typewriter Response:

F1F6F2F3

which indicates memory location 03F9 contains the hexadecimal number F1F6F2F3.

b. Memory Location Modification

One memory location may be modified using the following format:

+MOD LLLL, MMMMMMMM$^{n}_{1}$

where: LLLL is a 4 digit hexadecimal memory location which is to be modified with the value MMMMMMMM. Leading zeros must be included if LLLL is less than 4 digits or MMMMMMMM is less than 8 digits.

If the value is accepted, no typewriter response will be given. If the input is in error, the typewriter will respond with:

"ILLEGAL INPUT FORMAT"

Examples:

a) Keyboard Input:

+MOD 12C5, 6AF00834$^{n}_{1}$

Typewriter Response: None

b) Keyboard Input:

+MOD 1A61, F0F1F2F$^{n}_{1}$

Typewriter Response: ILLEGAL INPUT FORMAT (only 7 characters for modification value)

APPENDIX B

ATE BRIEFINGS

B.1 PRELIMINARY BRIEFING (Before Entering Cockpit)

Welcome to the first advanced experimental automated trainer. It is designed to demonstrate automated training in Ground Controlled Approaches and in selected in-flight emergency procedures. The training in these two areas will be conducted consecutively with emergency exercises following the GCA exercises.

From this point on, all actions will be taken by either you or the computer. No instructor will be involved. The purpose is to demonstrate the feasibility of automating certain types and phases of training; not to rule out the need for experienced and qualified instructors where and when needed.

The trainer you will be flying is a flexible research device. It has the flight characteristics of the F-4 aircraft. However, the cockpit does not contain typical F-4 instruments or consoles. Most sub-systems have not been included or simulated. For example, there is no navigation system, fuel system, or hydraulic system for you to control, although the effects are simulated where necessary.

The voice messages which you will receive in the cockpit will be from a computer-driven recorded voice system. Individual messages will be assembled word by word under computer direction. Thus individual words are formatted into sentences which provide instructions for take-off, climb-out, and GCA control.

Some of the words utilized in the instructions will be non-standard because of the word limitations in the recording system. Please accept this constraint and assume that standard voice procedures do exist. An operational trainer would, of course, incorporate the appropriate terminology required for the specific training involved.

You will not be able to talk to the computer to request information or to ask for a repeat. However, the exercise has been organized around computer checks. Should you miss an instruction and consequently fail to take the required actions, the computer will detect the discrepancy and either re-issue the instruction or provide new instructions as appropriate. There will be no need to acknowledge instructions.

Several safety procedures must be followed since the simulator incorporates motion. Basically, the procedures are typical aircraft procedures and include:

1. Complete all required check lists.

2. Fasten seat belt and shoulder harness.

3. Close and latch canopy.

An emergency switch is provided to turn off the cockpit motion. It is located on the top right portion of the instrument panel.

A safety operator is available to turn the system off at your request. A crash will also return the platform to ground level.

Please pick up the check lists on the table and enter the cockpit. Complete the pre-flight check list and when ready, conduct the engine start procedures. Further instructions will be transmitted at that time. Remember:

1. Insure that the canopy is closed and the seat belt and shoulder harness are fastened before starting the engines.

2. You cannot communicate with the computer other than by taking the directed actions.

3. There are no tricks or gimmicks involved. The training exercises are designed to develop selected flying skills in F-4 type aircraft.

Please take the check lists and enter the cockpit via the stairway on the right side of the simulator. Complete the pre-flight check list, start the engines by following the engine start check list, and await further instructions. Good luck, and good flying.

B. 2 INITIAL GCA COCKPIT BRIEFING (triggered by both engine start)

Welcome to the automated GCA trainer. This is your instructor talking with the aid of the computer system.

Several training sessions in Ground Controlled Approaches are planned. Each session will last about 45 minutes. The actual length of each session will depend on how well you do. Each succeeding GCA pass will become more difficult as you progress. The initial passes will be made with good runway wind conditions, nominal landing weights, and no turbulence. As successful passes are completed, landing weight and drag (external fuel and stores) will increase, wind down the runway will decrease, and turbulence will be encountered. These changing conditions will affect control characteristics of the aircraft and the difficulty of the GCA pass. The change in conditions will occur during climbout after each pass. However, all changes will be implemented prior to the beginning of the next GCA approach. Thus conditions will be relatively constant during the actual GCA pass. Fuel, for example, will not be consumed during a pass. You cannot run out of fuel. The procedures you should follow during these exercises will differ slightly from a standard GCA approach. Your climb-out instructions will always be to climb to 2500 feet at a specified heading. Wheels and flaps may be left down for the climb. On reaching 2500 feet, slow to approach speed (about 180 knots) and complete the landing check list. Your conditions will be monitored and when you are in landing configuration at the proper heading, angle of attack, and 2500 feet altitude, you will be handed over directly to your final controller.

Your glide slope angle of attack is set at 19.2 units, and the indexer may be used. Unless an "Execute Missed Approach" instruction is given, please continue the pass until over the runway and climb-out instructions are received. The runway for each succeeding pass will be straight ahead; you will not be required to circle the field.

Should you inadvertently crash, the computer will re-initialize the exercise at the beginning of the runway, and you will be required to take off and climb-out again, as instructed. Throttles should be brought back to idle after a crash to prevent a "premature" take-off.

At the beginning of the last pass, you will be cleared to land. Complete a full stop landing and cut the engines when you are stopped. The shut down check list should then be completed.

Other check lists are provided and should be used when indicated.

Take-off is fairly simple. Rudder control is adequate at 70 knots. Back pressure should be initiated at this point and maintained to hold 10° to 12° nose up pitch. The aircraft will fly off in this attitude. Hold this attitude and adjust the throttle to climb at about 200 knots. A higher speed only requires a longer time to set up landing conditions.

As outlined before, several safety procedures must be followed since the simulator incorporates motion. Basically these are typical aircraft procedures and include:

1. Complete required check lists.

2. Fasten seat belt and shoulder harness firmly before starting engine.

3. Close and latch the canopy.

A switch is provided on the upper right portion of the instrument panel to turn the cockpit motion off if necessary. A crash will return the platform to ground level. A safety operator will be available to turn off the system at your request. However, he will not be able to answer questions on the exercises, since they are entirely computer controlled.

Remember:

1. Insure canopy is closed and seat belt and shoulder harness are locked before starting engine.

2. You cannot communicate with the computer other than by taking the directed actions.

3. There are no tricks or gimmicks in these exercises. They are designed to develop or improve GCA skills in an F-4 type aircraft.

Also remember that as you improve, the process will become more challenging.

Now, get ready for take-off clearance; and when cleared, take off straight ahead. Climb out on assigned course to 2500 feet with gear and flaps down, conduct the landing check, establish the landing angle of attack at 19.2 units, and await further instructions. You must establish the landing configuration with the proper angle of attack before you will be handed over to the final controller.

Remember, conditions may change prior to each approach, so do not be surprised if control effectiveness changes before each pass.

Now, stand by for erection of the motion system and take-off clearance. Good luck, and good flying.

B.3 SUBSEQUENT GCA COCKPIT BRIEFINGS

Welcome back to automated training. Additional GCA passes will be conducted today, much as they were on your last flight. In addition, several emergency procedures will be practiced if you complete the GCA syllabus during this session. The emergencies include a single engine GCA approach. Engine failure can occur anytime from level flight to GCA minimums. The single engine check list should therefore be reviewed. The procedure is straight forward: continue the GCA approach by advancing the throttle of the good engine to military power or after burner as necessary; raise the flaps to 1/2 and hold the angle of attack at 17 units. After completing the pass, and if climb-out instructions are received, relight the failed engine prior to the next approach. If cleared to land, however, continue the single engine approach to touchdown.

The other emergency which will be practiced will be loss of communications during GCA approach. The procedures will be given by your final controller. Basically, you will be required to execute a wave-off, climb to 2500 feet, and begin a holding pattern with 1 minute legs.

Engine failure may also occur with a loss of communications. In this case, execute a single engine wave-off and begin the required holding pattern. The engine should be restarted only after communications have been established. Any attempt to restart the engine prior to restoration of communications will be unsuccessful.

Remember, the emergencies will consist of engine failure, loss of communications, or both. Attempts to relight the failed engine until climb-out is directed will be unsuccessful.

Now, stand by for erection of the motion system and take-off clearance. Take-off will be straight ahead. Climb out on assigned course at about 200 knots to 2500 feet with wheels and flaps down, and then establish landing configuration. Good luck, and good flying.

91

APPENDIX C

ATE CHECK LISTS

PRE-START CHECK LIST

Left Console

1. Wing Station - NORMAL
2. Center Station - NORMAL
3. Throttles - OFF
4. Speed Brakes - CYCLE IN
5. Engine Masters - OFF
6. Engine Start - OFF

Panel

1. Gear Handle - DOWN
2. Motion - OFF
3. Accelerometer - ZERO RESET
4. Rudder Pedals - ADJUST

Right Console

1. Warning Light - TEST (MOTION)
2. Instrument Panel Lights - ON, ADJ.
3. Console Lights - ON, ADJ
4. Indexer - ON, ADJ
5. Intercom Volume - ADJ

PRE TAKE OFF

1. Canopies: L LOCKED - R LOCKED
2. Seat Belt/SH - FASTENED
3. Speed Brakes - IN
4. Flaps - 1/2
5. Trim - 2 UNITS NOSE DOWN
6. Controls - FREE
7. Motion - ARMED

SINGLE ENGINE LDG CHECK

1. Throttle - POWER AS REQ
2. Flaps - RAISE TO 1/2
3. Angle of attack - 17 UNITS

ENGINE START

Right Engine First

1. Engine Master - ON
2. Engine Start - ON
3. Throttle - ADV TO IDLE AT 10% RPM
4. Ignition - PRESS AT 10% RPM

After Ignition -

1. Engine Start - OFF

Repeat for left engine.

CLIMB PROCEDURES

1. Gear - DOWN
2. Flaps - FULL
3. Pitch - 10° UP
4. Speed - 200 kts

Level at 2500 feet.

LANDING CHECK

1. Speed Brake - IN
2. Gear - DOWN
3. Flaps - FULL
4. Establish AOA - 19.2 UNITS

Hold 2500 feet altitude.

SHUT DOWN CHECK LIST

1. Throttles - OFF
2. Engine Master - OFF
3. Motion - OFF
4. Instrument Panel Lights - OFF
5. Console Lights - OFF
6. Indexer - OFF

APPENDIX D

PILOT COMMENTS ON THE F4 AUTOMATED TRAINER EVALUATION (ATE) PROGRAM

INTRODUCTION

Pilot comments have long been recognized as an extremely valuable input to system design. This is especially true for flight simulators development. The following questions are intended to cover some of the major points of the simulation system you have just flown. You undoubtedly will have other comments to make. Please feel free to write them down or record them on the tape recorder if you desire. Your inputs to design features of automated training now can prevent the incorporation of undesirable features when actual trainers are built.

INSTRUCTIONS

1. Read and evaluate each question carefully.

2. Check the category which best reflects your evaluation. Check only one category for each question.

3. If unable to evaluate a specific question, check the category "Undecided". However, try to analyze your thoughts and avoid the "Undecided" category.

4. Please answer all questions.

5. If you have any specific comments or recommendations, please list them under the Comments/Recommendations section provided at the end of the questionnaire, or record them on the tape recorder provided.

95

PILOT NAME DATE

1. How would you compare the handling characteristics, in general, of the simulator with the actual F-4E aircraft:

   Very Good ___ Good ___ Satisfactory ___ Poor ___ Have not flown F-4 ___

2. How would you evaluate the following specific simulator characteristics as compared to the actual F-4E aircraft?

   A. Pitch response to stick inputs? Very Good ___ Good ___ Satisfactory ___ Poor ___ Undecided ___

   B. Roll responses to stick inputs? Very Good ___ Good ___ Satisfactory ___ Poor ___ Undecided ___

   C. Yaw response to rudder pedal inputs? Very Good ___ Good ___ Satisfactory ___ Poor ___ Undecided ___

   D. Engine response to throttle inputs? Very Good ___ Good ___ Satisfactory ___ Poor ___ Undecided ___

3. How would you evaluate the simulator during the GCA approach as to:

   A. Attitude control? Very Good ___ Good ___ Satisfactory ___ Poor ___ Undecided ___

   B. Vertical velocity control? Very Good ___ Good ___ Satisfactory ___ Poor ___ Undecided ___

   C. Heading control? Very Good ___ Good ___ Satisfactory ___ Poor ___ Undecided ___

   D. Trim characteristics control? Very Good ___ Good ___ Satisfactory ___ Poor ___ Undecided ___

4. How would you rate the pre-exercise audio tape briefings?

Very Good ___ Good ___ Adequate ___ Inadequate ___ Undecided ___

5. How would you rate the cockpit audio tape briefing?

Very Good ___ Good ___ Adequate ___ Inadequate ___ Undecided ___

6. What is your evaluation with respect to the length of each session?

Too Long ___ About Right ___ Too Short ___ Undecided ___

7. With respect to the GCA approach exercise, how would you evaluate:

A. The quality of voice transmissions? Very Good ___ Good ___ Satisfactory ___ Poor ___ Undecided ___

B. The frequency of voice transmissions? Too Often ___ About Right ___ Too Infrequent ___ Undecided ___

C. Vertical glide path information (above glide path, below glide path, on glide path, etc.)? Very Good ___ Good ___ Adequate ___ Inadequate ___ Undecided ___

D. Heading control information (heading is good, turn right, etc.)? Very Good ___ Good ___ Adequate ___ Inadequate ___ Undecided ___

E. General information transmissions (wind data, runway data, climb instructions, etc.)? Very Good ___ Good ___ Adequate ___ Inadequate ___ Undecided ___

F. The glide slope tolerances for wave-off? Too Tight ___ About Right ___ Too Loose ___ Undecided ___

8. How would you evaluate the increasing difficulty of the task as training progressed?

   Too Hard ____ About Right ____ Too Easy ____ Undecided ____

9. How would you evaluate the following parameters with respect to increasing the difficulty of the exercise:

   A. The incremental change of wind velocity from a head wind to a tail wind? Too Hard ____ About Right ____ Too Easy ____ Undecided ____

   B. The addition of internal fuel and external stores which affected the aircraft's stability? Too Hard ____ About Right ____ Too Easy ____ Undecided ____

   C. The increase in turbulence? Too Hard ____ About Right ____ Too Easy ____ Undecided ____

10. How would you evaluate the GCA exercise for its effectiveness in:

   A. Training pilots with no previous GCA experience? Very Good ____ Good ____ Satisfactory ____ Poor ____ Undecided ____

   B. Maintaining proficiency for qualified GCA pilots? Very Good ____ Good ____ Satisfactory ____ Poor ____ Undecided ____

11. With respect to the emergency procedures, how would you evaluate the realism of:

   A. The communications failures? Realistic ____ Partially Realistic ____ Unrealistic ____ Undecided ____

   B The engine failures? Realistic ___ Partially Realistic ____ Unrealistic ____ Undecided ____

COMMENTS OR RECOMMENDATIONS: (Please list below or record on tape provided)

AUTOMATED TRAINER EVALUATION

Flight Experience Forms
(Return to Code 554)

NAME ______________________ CODE ________ EXTENSION ________

	General Experience				
	Pilot		Co Pilot		Other
	Jet	Prop	Jet	Prop	
Total Flight Time					
Last Six Months					X
IFR					X
Flight Simulator			X	X	X
# of GCA's			X	X	X

Specific Experience

Aircraft Model	Hours	# of GCA's

Simulator Model or Designation	Hours

Last Flight Model ______________ Date ________ Hours ______

Last GCA Model ______________ Date ________

Last Simulation Run Model ______________ Date ________ Hours ____

APPENDIX E

NTDC COGNITRONICS WORD LIST

COGNITRONICS VOCABULARY (ALPHABETIC)

*ABOVE	21	*EXECUTE	2B	MINUTE	35	SILENCE	0A
*ACKNOWLEDGE	61	FAST	1F	*MISSED	75	*(SILENCE)	00
AFTER	A1	*FEET	6B	NAUTICAL	B5	(SILENCE)	40
AGAIN	13	*FINAL	AB	*NAVY	36	(SILENCE)	80
ALPHA	4A	*FIVE	07	*NINE	48	*SIX	47
ALSO	22	*FOR	2C	*NINER	88	*SLIGHTLY	3E
ALTITUDE	62	FORWARD	56	*NO	76	SLOW	9E
*AND	A2	*FOUR	86	NORMAL	B6	SOUTH	1B
ANSWER	53	FOXTROT	0C	NORTH	98	SPEED	5B
*APPROACH	23	*FROM	6C	NOSE	19	START	9B
*APPROACHING	63	*FURTHER	AC	*NOT	37	STICK	1C
ARE	93	*GLIDE	2D	NOVEMBER	8E	SURFACE	7E
*AT	A3	GOLF	4C	OBSERVER	77	*TAKE	BE
AVAILABLE	24	*GOOD	6D	*OF	B7	TANGO	90
BACK	14	GUSTY	AD	*OFF	59	THAT'S	5C
BE	96	*HALF	49	*ON	38	*THE	3F
BEEN	64	*HEADING	2E	*ONE	85	THESE	9C
*BEGIN	A4	HEAR	6E	OR	78	THIS	7F
*BELOW	25	HELLO	17	OSCAR	0F	THOUSAND	BF
BRAVO	8A	HOTEL	8C	*OVER	B8	*THREE	46
CANCELLED	65	HOW	AE	PAPA	4F	*THRESHOLD	20
CHARLIE	0B	*HUNDRED	2F	*PATH	39	*TO	60
CLEAR	A5	*IF	6F	PATTERN	79	*TOUCHDOWN	A0
CLEARENCE	66	IMMEDIATELY	57	PEDDLE	99	TOWER	01
*CLEARED	26	*IN	AF	PER	B9	*TRANSMISSION	41
*CLIMB	A6	INCREASE	97	PERFORM	3A	*TURN	81
*COMPLETE	27	INDIA	0D	PLEASE	9F	*TWO	06
CONFIRMED	67	INFORMATION	30	PLUS	1A	*UNABLE	02
*CONTACT	A7	*IS	70	POINT	7A	UNIFORM	11
CONROL	5E	JULIET	4D	*PRECISION	BA	UP	1D
*CONTROLLER	28	KILO	8D	PRESENT	5A	VICTOR	51
*CORRECT	54	*KNOTS	B0	QUARTER	09	VISIBILITY	42
CORRECTED	68	*LAND	31	*QUARTERS	89	VISUAL	82
CORRECTION	A8	*LANDING	71	QUEBEC	8F	*VISUALLY	03
COURSE	29	*LEFT	B1	*RATE	3B	*WELL	43
DAY	69	LEFT OF	32	*RECEIVED	7B	WEST	5D
DECREASE	94	LEVEL	18	RECOMMEND	5F	WHEELS	83
*DEGREES	A9	LIGHTS	72	*RIGHT	BB	WHISKEY	91
DELTA	4B	LIMA	0E	RIGHT OF	3C	*WIND	04
DESCEND	15	LOUD	B2	ROGER	7C	WING	9D
*DESCENT	2A	*MAINTAIN	33	ROMEO	10	WITH	1E
DIVE	55	ME	73	*RUNWAY	BC	WITHIN	44
*DO	6A	MIKE	4E	*SECONDS	3D	XRAY	12
DOWN	AA	*MILE	B3	*SETTINGS	9A	YANKEE	52
EASE	95	*MILES	34	*SEVEN	87	YOU	84
EAST	16	*MINIMA	74	SHOULD	7D	YOUR	05
ECHO	8B	MINIMUM	B4	SIERRA	50	*ZERO	45
*EIGHT	08	MINUS	58	*SIGHT	BD	ZULU	92

* Words currently employed in ATE Program.

COGNITRONICS VOCABULARY NUMERICALLY (HEXADECIMAL)

00*	(SILENCE)	30	INFORMATION	60*	TO	90	TANGO
01	TOWER	31*	LAND	61*	ACKNOWLEDGE	91	WHISKEY
02*	UNABLE	32	LEFT OF	62	ALTITUDE	92	ZULU
03*	VISUALLY	33*	MAINTAIN	63*	APPROACHING	93	ARE
04*	WIND	34*	MILES	64	BEEN	94	DECREASE
05	YOUR	35	MINUTE	65	CANCELLED	95	EASE
06*	TWO	36*	NAVY	66	CLEARENCE	96	BE
07*	FIVE	37*	NOT	67	CONFIRMED	97	INCREASE
08*	EIGHT	38*	ON	68	CORRECTED	98	NORTH
09	QUARTER	39*	PATH	69	DAY	99	PEDDLE
0A	SILENCE	3A	PERFORM	6A*	DO	9A*	SETTINGS
0B	CHARLIE	3B*	RATE	6B*	FEET	9B	START
0C	FOXTROT	3C	RIGHT OF	6C*	FROM	9C	THESE
0D	INDIA	3D*	SECONDS	6D*	GOOD	9D	WING
0E	LIMA	3E*	SLIGHTLY	6E	HEAR	9E	SLOW
0F	OSCAR	3F*	THE	6F*	IF	9F	PLEASE
10	ROMEO	40	(SILENCE)	70*	IS	A0*	TOUCHDOWN
11	UNIFORM	41*	TRANSMISSION	71*	LANDING	A1	AFTER
12	XRAY	42	VISIBILITY	72	LIGHTS	A2*	AND
13	AGAIN	43*	WELL	73	ME	A3*	AT
14	BACK	44	WITHIN	74*	MINIMA	A4*	BEGIN
15	DESCEND	45*	ZERO	75*	MISSED	A5	CLEAR
16	EAST	46*	THREE	76*	NO	A6*	CLIMB
17	HELLO	47*	SIX	77	OBSERVER	A7*	CONTACT
18	LEVEL	48*	NINE	78	OR	A8	CORRECTION
19	NOSE	49*	HALF	79	PATTERN	A9*	DEGREES
1A	PLUS	4A	ALPHA	7A	POINT	AA	DOWN
1B	SOUTH	4B	DELTA	7B*	RECEIVED	AB*	FINAL
1C	STICK	4C	GOLF	7C	ROGER	AC*	FURTHER
1D	UP	4D	JULIET	7D	SHOULD	AD	GUSTY
1E	WITH	4E	MIKE	7E	SURFACE	AE	HOW
1F	FAST	4F	PAPA	7F	THIS	AF*	IN
20*	THRESHOLD	50	SIERRA	80	(SILENCE)	B0*	KNOTS
21*	ABOVE	51	VICTOR	81*	TURN	B1*	LEFT
22	ALSO	52	YANKEE	82	VISUAL	B2	LOUD
23*	APPROACH	53	ANSWER	83	WHEELS	B3*	MILE
24	AVAILABLE	54*	CORRECT	84	YOU	B4	MINIMUM
25*	BELOW	55	DIVE	85*	ONE	B5	NAUTICAL
26*	CLEARED	56	FORWARD	86*	FOUR	B6	NORMAL
27*	COMPLETE	57	IMMEDIATELY	87*	SEVEN	B7*	OF
28*	CONTROLLER	58	MINUS	88*	NINER	B8*	OVER
29	COURSE	59*	OFF	89*	QUARTERS	B9	PER
2A*	DESCENT	5A	PRESENT	8A	BRAVO	BA*	PRECISION
2B*	EXECUTE	5B	SPEED	8B	ECHO	BB*	RIGHT
2C*	FOR	5C	THATS	8C	HOTEL	BC*	RUNWAY
2D*	GLIDE	5D	WEST	8D	KILO	BD*	SIGHT
2E*	HEADING	5E	CONTROL	8E	NOVEMBER	BE*	TAKE
2F*	HUNDRED	5F	RECOMMEND	8F	QUEBEC	BF	THOUSAND

* Words currently employed in ATE Program.

APPENDIX F

STANDARD GCA PAR PHRASEOLOGY

The following is the phraseology utilized by PAR controllers. The abbreviation "Ident." refers to the aircraft identification or call number.

"(Ident.) Radar Contact _____ miles from touchdown, Final Controller. When on final if no transmission received for five seconds, take over visually. If unable, continue with TACAN approach or execute missed approach."

"(Ident.) Published Decision Height _____ feet, if runway not in sight at Decision Height, climb and maintain _____ feet immediately and execute missed approach."

"(Ident.) On final, do not acknowledge further transmission. Approaching glide-path, begin descent."

"3 miles from touchdown"

"2 1/2 miles from touchdown, cleared _____, runway _____, wind _____."

"2 miles from touchdown"

"1 1/2 miles from touchdown"

"1 mile from touchdown"

(3/4 mile) "At published decision height"

"1/2 mile from touchdown, take over visually, runway centerline information"

"Over landing threshold"

"Over touchdown"

The following are typical glide slope and course instruction phrases.

"well above glide path"

"above glide path"

103

"slightly above glide path"

"on glide path"

"slightly below glide path"

"below glide path"

"well below glide path"

"on course"

"turn right to heading"

"turn left to heading"

"assigned heading is"

In addition rate information is frequently given in terms of

"on glide path and holding"

"going below (or above) glide path"

"approaching glide path"

APPENDIX G

AUTOMATED GCA TRAINING PHRASEOLOGY

The following oral instructions were utilized prior to and during PAR control The identification "Navy 1 2 3" was used throughout. Phraseology reflects COGNITRONICS word list and data.

"complete take-off settings"

"cleared for take-off"

"climb and maintain 2500 feet, heading 045 degrees"

"complete landing settings"

"contact, 9 miles from touchdown, final controller"

"if on final and no transmission received for 5 seconds, take over visually; if unable, execute missed approach."

"precision minima 200 feet, 1/2 mile; if runway not in sight at minima, complete approach to touchdown if the transmission to execute missed approach is not received."

"on final, do not acknowledge further transmission; approaching glide path, begin correct rate of descent"

*"5 miles from touchdown"

*"3 miles from touchdown"

*"2 1/2 miles from touchdown"

*"2 miles from touchdown"

*"1 1/2 miles from touchdown"

*"1 mile from touchdown"

*"3/4 mile from touchdown"

*"1/2 mile from touchdown"

*"cleared runway 04"

*"over landing threshold"

"over touchdown"

"correct heading is ______"

"heading is good"

"turn left heading ______"

"turn right heading ______"

"well above glide path"

"above glide path"

"slightly above glide path"

"on glide path"

"slightly below glide path"

"below glide path"

"well below glide path"

"wind ______, ______ knots"

"execute missed approach; execute missed approach"

**"complete descent, cleared to land"

*Optional - Transmitted by program if no higher priority message
**Used on final pass in any session.

APPENDIX H

ATE B/F MODULE FUNCTIONAL DESCRIPTIONS

H. 1 ATE MAJOR FOREGROUND MODULES

1. COGNITRONICS Message Processor (COG)

2. ATE Glide Path Dynamics (GPD)

3. Compute SIN/COS for Runway Orientation (RSC)

H. 1. 1 Program Module Name

COGNITRONICS Message Processor (COG)

H. 1. 1. 1 Purpose. The purpose of COG is to monitor and control all COGNITRONICS output messages.

H. 1. 1. 2 Requirements. The COG program module is required:

1. To select and place in the COGNITRONICS output buffer the next COGNITRONICS output word address.

2. To deactivate the COGNITRONICS output routines if no further message words are awaiting output.

3. To manipulate the COGNITRONICS message queue to insure the correct order and priority of message output.

4. To insert new messages into the COGNITRONICS queue in order of priority, when required.

5. To purge the COGNITRONICS queue upon request.

H. 1. 1. 3 Description. A description of the operation of the COGNITRONICS Speechmaker can be found in the COGNITRONICS Operation and Maintenance Manual. Messages for the GCA and Emergency Procedures Exercises are assembled by the Meta-Symbol Procedure (PROC) 'CMSG' in this program. The 1st word of each CMSG contains the priority, group, sequence number and pointer to the next message in the output queue, if any. The 1st byte of the 2nd word indicates the number of words contained in the message. All successive bytes contain the COGNITRONICS addresses of the message string.

Messages awaiting output are queued together in order of priority by the QINSERT subroutine which is callable from any ATE Background program module. Once a message has started being processed for output by the COG:1 routine it cannot be replaced at the top of the message queue by another message which is to be inserted in the queue. The COG:1 routine interrogates the KCOG counter (set by the COGNITRONICS interrupt in the MCC module) to determine if the COGNITRONICS is ready to accept the next word address in the message queue. COG:1 is activated whenever a call is made to the QINSERT routine and is deactivated when the message queue is empty.

The QPURGE routine purges the COGNITRONICS message queue. It is usually employed whenever the run is terminated or when a CRASH or RESET-TO-ZERO condition is detected.

The following COGNITRONICS messages are employed in the ATE programs.

CLIMB AND MAINTAIN 2500 FEET, HEADING 045 DEGREES

CLEARED RUNWAY 04

CORRECT HEADING IS _____

HEADING IS GOOD

TURN LEFT HEADING _____

TURN RIGHT HEADING _____

NAVY 123, CONTACT 9 MILES FROM TOUCHDOWN, FINAL CONTROLLER

NAVY 123, IF ON FINAL AND NO TRANSMISSION IS RECEIVED FOR 5 SECONDS TAKE OVER VISUALLY; IF UNABLE EXECUTE MISSED APPROACH

NAVY 123, PRECISION MINIMA 200 FEET, 1/2 MILE; IF RUNWAY NOT IN SIGHT AT MINIMA, COMPLETE APPROACH TO TOUCHDOWN IF THE TRANSMISSION TO EXECUTE MISSED APPROACH IS NOT RECEIVED

NAVY 123, ON FINAL, DO NOT ACKNOWLEDGE FURTHER TRANSMISSION; APPROACHING GLIDE PATH, BEGIN CORRECT RATE OF DESCENT

COMPLETE LANDING SETTINGS

5 MILES FROM TOUCHDOWN

3 MILES FROM TOUCHDOWN

2 1/2 MILES FROM TOUCHDOWN

2 MILES FROM TOUCHDOWN

1 1/2 MILES FROM TOUCHDOWN

1 MILE FROM TOUCHDOWN

3/4 MILE FROM TOUCHDOWN

1/2 MILE FROM TOUCHDOWN

OVER LANDING THRESHOLD

OVER TOUCHDOWN

CLEARED FOR TAKE OFF

COMPLETE TAKE OFF SETTINGS

COMPLETE DESCENT; CLEARED TO LAND

ABOVE GLIDE PATH

BELOW GLIDE PATH

ON GLIDE PATH

SLIGHTLY ABOVE GLIDE PATH

SLIGHTLY BELOW GLIDE PATH

WELL ABOVE GLIDE PATH

WELL BELOW GLIDE PATH

WIND ______, ______ KNOTS

EXECUTE MISSED APPROACH; EXECUTE MISSED APPROACH

H. 1. 2 Program Module Name

ATE Glide Path Dynamics (GPD)

H. 1. 2. 1 Purpose. The purpose of GPD is to compute the X, Y, and Z coordinates of the aircraft relative to the GCA glide path.

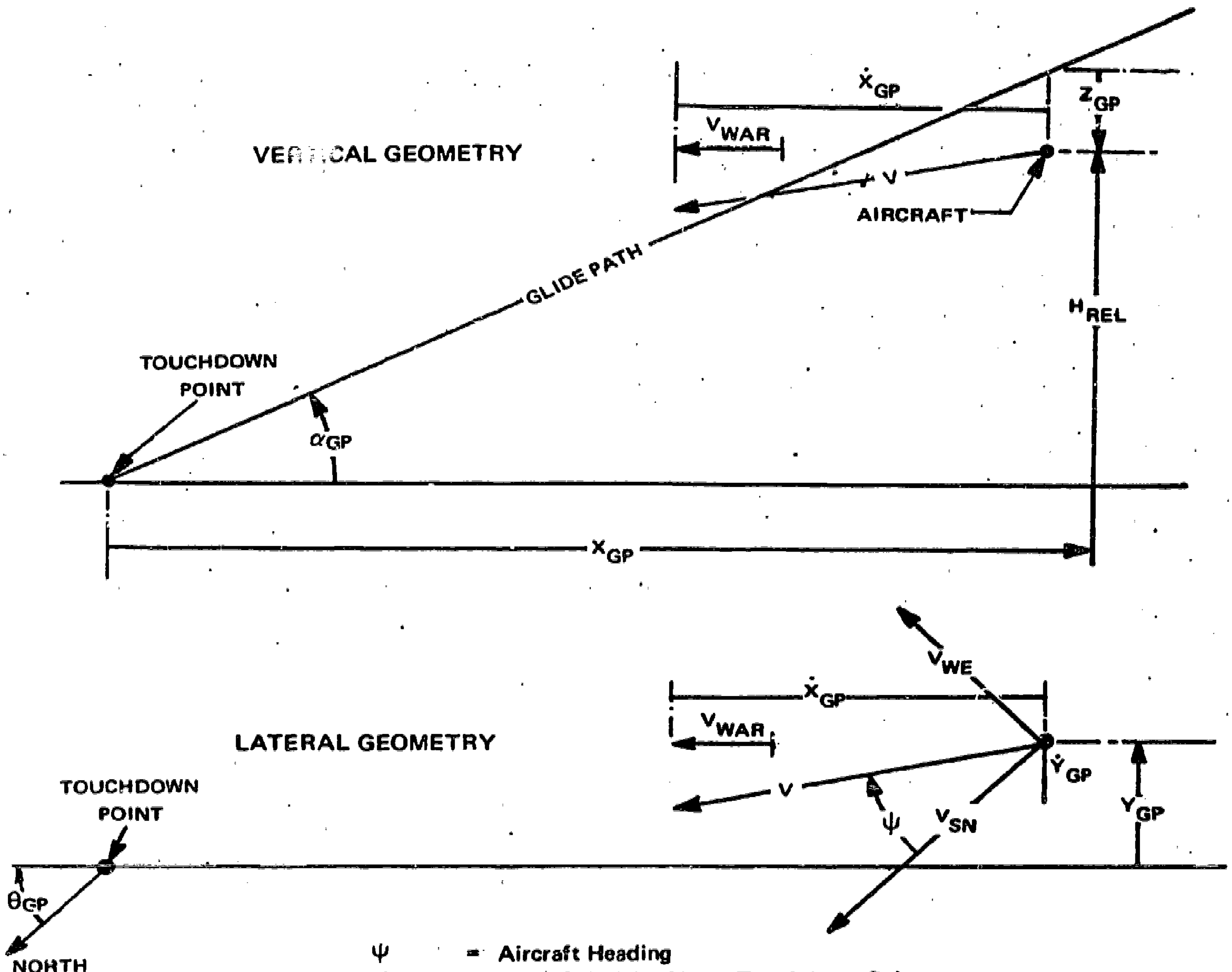
H. 1. 2. 2 Requirements. GPD is required to compute:

1. The X, Y and Z coordinates of the aircraft relative to the GCA glide path.

2. The X and Y rate terms ($\dot{X}$, $\dot{Y}$) of the aircraft relative to the GCA glide path.

H. 1. 2. 3 Description. Figure 15 illustrates the vertical and lateral geometry of the glide path dynamics employed in the ATE, GCA Exercise. The following mathematical relationships are employed to determine the position and velocity of the aircraft relative to the glide path and point of touchdown:

$$\dot{X}_{GP} = V_{WAR} - V_{SN} \cos (\theta_{GP}) - V_{WE} \sin (\theta_{GP})$$



ψ = Aircraft Heading
H_{REL} = Aircraft Height Above Touchdown Point
α_{GP} = Glide Slope Angle
θ_{GP} = Glide Path Centerline Azimuth
V = Aircraft Velocity Vector
X_{GP} = Distance from Touchdown (Nautical Miles)
Y_{GP} = Distance to the Right of Glide Path (Nautical Miles)
Z_{GP} = Distance Below Glide Path (Feet)
$\dot{X}_{GP}$ = Aircraft Velocity Along Glide Path
$\dot{Y}_{GP}$ = Aircraft Velocity Across Glide Path
V_{WE} = Aircraft Velocity — West to East
V_{SN} = Aircraft Velocity — South to North
V_{WAR} = Wind Velocity Along Runway

Figure 15. ATE Glide Path Geometry

$$\dot{Y}_{GP} = V_{SN} \sin (\theta_{GP}) + V_{WE} \cos (\theta_{GP})$$

where:

$$V_{SN} = V \cos (\psi)$$

$$V_{WE} = V \sin (\psi)$$

$$X_{GP}(t + \Delta t) = X_{GP}(t) + \int_{t}^{t+\Delta t} X_{GP} dt$$

$$Y_{GP}(t + \Delta t) = Y_{GP}(t) + \int_{t}^{t+\Delta t} Y_{GP} dt$$

$$Z_{GP} = X_{GP} \tan (\alpha_{GP}) - H_{REL}$$

Since the ATE Glide Path Dynamics equations are computed at a constant time interval of 50 milliseconds the X and Y components of distance can be simplified to the following form:

$$X_{GP\,(I)} = X_{GP\,(I-1)} + X_{GP\,(I)} \cdot \text{PKGPD4}$$

$$Y_{GP\,(I)} = Y_{GP\,(I-1)} + Y_{GP\,(I)} \cdot \text{PKGPD4}$$

where:

I = Present computer cycle time (t)

I - 1 = Previous computer cycle time (t - 50 milliseconds)

PKGPD4 = Conversion factor KNOTS to NAUTICAL MILES for 50 millisecond interval

$$= \left(\frac{1}{20 \text{ Sec}}\right) \cdot \left(\frac{1}{3600 \text{ Sec}}\right) = \left(\frac{1}{72,000}\right)$$

$$= 1.388888888 \times 10^{-5}$$

112

Since the glide path remains fixed during the run, the following values can be computed before the start of the run and can be used as constants throughout the run:

$$PKGPD1 = -\cos(\theta_{GP})$$

$$PKGPD2 = -\sin(\theta_{GP})$$

$$PKGPD3 = \tan(\alpha_{GP})$$

The equations used by the program can thus be reduced to:

$$V_{SN} = V\cos(\psi)$$

$$V_{WE} = V\sin(\psi)$$

$$\dot{X}_{GP} = V_{WAR} + (PKGPD1)(V_{SN}) + (PKGPD2)(V_{WE})$$

$$\dot{Y}_{GP} = (PKGPD2)(V_{SN}) - (PKGPD1)(V_{WE})$$

$$X_{GP} = X_{GP\,(I-1)} + (PKGPD4)(X_{GP})$$

$$Y_{GP} = Y_{GP\,(I-1)} + (PKGPD4)(Y_{GP})$$

$$Z_{GP} = (PKGPD3)(X_{GP}) - H_{REL}$$

H. 1. 3 Program Module Name

Compute SIN/COS for Runway Orientation (RSC)

H. 1. 3. 1 Purpose. The purpose of RSC is to compute, in the foreground mode, the SIN/COS of any new program parameters entered prior to the start of the GCA run.

H. 1. 3. 2 Requirements. RSC is required to compute and save the following parameters:

1.	PGCASIN	Sine of Heading Limits
2.	PGCACOS	Cosine of Heading Limits
3.	PKGPD1	$-\cos(\theta_{GP})$
4.	PKGPD2	$-\sin(\theta_{GP})$

H. 1. 3. 3 Description. This module was designed to be executed in the F-4 foreground mode since it was desired to take advantage of the existing sine/cosine routines in the F-4 program. The F-4 sine/cosine routine does not, however, provide for re-entrant coding. In order to prevent possible destruction of computational results for the background mode, it was necessary to perform the sine/cosine computations in the foreground mode.

This routine is entered once only prior to the start of each GCA run to compute values which will remain constant throughout that particular run, i. e., sin/cos of heading limits used in the Pre-GCA configuration check (PGCA) and the sin/cos of glide path azimuth angle (θ_{GP}) used in the Glide Path Dynamics computations.

H. 2 ATE MAJOR BACKGROUND MODULES

1. Exercise Scheduler (EXSC)
2. Terminate Exercise (EXTR)
3. Pre-Airborne (PAB)
4. GCA Initialize (GCIN)
5. Pre-GCA Configuration Check (PGCA)
6. GCA Controller (CONT)
7. Emergency Procedure Processor (EMRP)

8. Data Processing (DATP)

9. Adaptive Logic (ALOG)

H. 2. 1 Program Module Name

Exercise Scheduler (EXSC)

H. 2. 1. 1 Purpose. The purpose of EXSC is to determine which ATE Exercise has been selected and to setup the proper program linkages for its execution.

H. 2. 1. 2 Requirements. EXSC is required to:

1. Determine which ATE Exercise has been selected via the System Sense Switches, typewriter input or the Adaptive Logic program

2. Set-up the proper program linkages for the selected exercise

3. Initialize selected exercise parameters

4. Activate the correct program modules to successfully monitor the selected exercise

5. Select the Difficulty Level for the current exercise

H. 2. 1. 3 Description. EXSC may be activated by one of the following three methods:

1. Input through the System Sense Switch Console

2. Input through the Typewriter

3. Internally by the ATE Program upon completion of a particular run (if not the last run of a session)

Entry by one of the first two methods requires that the exercise be provided by the operator while the third method is determined by the program automatically.

Currently, two exercises are available: (1) the GCA Approach, and (2) Emergency Procedures. The program is designed to permit the incorporation of additional exercises, as desired, with the minimum of program changes.

In addition to the selection of the exercise and the initialization of certain parameters, EXSC also selects the difficulty levels to be used for the next run. This is done by calling the DFSELECT subroutine contained in the ALOG program module.

H 2.2 Program Module Name

Terminate Exercise (EXTR)

H. 2. 2. 1 Purpose. The purpose of EXTR is to terminate the current ATE Exercise and, if required, the ATE Session.

H. 2. 2. 2 Requirements. EXTR is required to:

1. Examine the exercise status upon completion of the current run.
2. Output to the typewriter and line printer the reason for run termination.
3. Increment the run number.
4. Output to COGNITRONICS climb instructions if another run is to follow.
5. Output to COGNITRONICS landing instructions if the session has been completed.
6. Reset the engine flame-out parameters to permit engine restart, if necessary.
7. Initialize program routing parameters.

H. 2. 2. 3 Description. During the execution of the various ATE exercises, various run status data is retained for use by the EXTR program. EXTR evaluates this data for subsequent program routing and future exercise/run selection.

Upon entry, the engine flame-out parameters (FOLE, FORE) are reset to permit engine restart in case either engine had been shut down by the EMRP program. Next the program checks to see if this is to be the last run of the session. The last run of any session is signified when any of the following occurs:

1. Successful completion of the last scheduled run of the last ATE Exercise.

2. Completion of the maximum number of runs permitted per session.

3. Maximum time allotted per session has been exceeded.

The program increments the run number and then examines the termination code (TERMCODE) supplied by other ATE program modules and outputs to the typewriter and line printer the reason for termination of the run. Runs are terminated by:

1. Successful completion of the run

2. GCA approach lateral wave-off

3. GCA approach vertical wave-off

4. Aircraft 'CRASH' prior to actual start of run

5. Aircraft 'CRASH' during run

6. System console sense switch request

7. Expiration of allotted time for Emergency Procedure response

Depending upon whether or not another run is to follow, EXTR outputs to the COGNITRONICS either climbout or landing instructions.

H. 2. 3 Program Module Name

Pre-Airborne (PAB)

H. 2. 3. 1 Purpose. The purpose of PAB is to monitor the subjects actions from the time of initialization until the aircraft is airborne.

H. 2. 3. 2 Requirements. PAB is required to:

1. Issue Audio Briefing instructions upon detection of engine start.

2. Supply the AMOD program module with the initial difficulty factors.

3. Monitor the 'RESET-TO-ZERO' button on the Monitor Console for completion of the Audio Briefing.

4. Check for proper Take-Off Configuration of aircraft.

5. Issue COGNITRONICS and/or Typewriter messages if in improper take-off configuration for a specified time period.

6. Issue take-off instructions when aircraft is in proper configuration.

7. Check for aircraft airborne.

H. 2. 3. 3 Description. The Pre-Airborne program module was designed to monitor the cockpit inputs provided by the subject prior to aircraft lift-off. It consists of the following four phases:

1. Phase 0 - The program tests for the presence of engine start which indicates the pilot is ready for the audio briefing. At

this point a message is typed out to commence the audio briefing and the initial difficulty factors are selected for the AMOD program. The program then advances to phase 1.

2. Phase 1 - The program now tests for the completion of the audio briefing. Since no computer controlled audio tape is currently employed, this action is simulated via the 'RESET-TO-ZERO' button on the Monitor Console. When this button is released the program assumes that the audio briefing for the selected exercise has been completed and the program advances to phase 2.

3. Phase 2 - This is the pre-takeoff configuration check phase. The program checks the following aircraft parameters to insure that the aircraft is in a satisfactory configuration for take off:

   a. Landing Gear Down.

   b. Flaps in 1/2 Position.

   c. Engine Flame (Both Engines).

   d. Aircraft on Ground.

   e. Speed Brake-In.

   If, after a 30 second time period, the above conditions have not been met, a message is sent via the COGNITRONICS saying 'CHECK TAKE-OFF SETTINGS' and another message to the typewriter stating 'IMPROPER TAKE-OFF CONFIGURATION'. Each 30 second period thereafter, if the aircraft is still not in the proper configuration, the COGNITRONICS message is repeated and one or more of the following messages is sent to the typewriter:

   a. CHECK WHEELS UP

   b. CHECK FLAP POSITION

   c. CHECK SPEED BRAKE OUT

   d. CHECK ENGINES

   e. CHECK A/C ON GROUND

Because of the limited COGNITRONICS vocabulary it was not possible to implement the above messages for voice output.

Once the proper take-off configuration has been attained, the message 'CLEARED FOR TAKE-OFF' is sent to the COGNITRONICS and typewriter. The program then advances to phase 3.

4. Phase 3 - During this phase a test is performed to detect aircraft lift-off. When detected, the message 'AIRCRAFT AIRBORNE' is typed out, the Pre-GCA Program module (PGCA) is activated and PAB is de-activated.

H. 2.4 Program Module Name

GCA Initialize (GCIN)

H. 2. 4. 1 Purpose. The purpose of GCIN is to initialize all GCA parameters needed for the current run.

H. 2. 4. 2 Requirements. GCIN is required to:

1. Initialize Distance-To-Go Message Switches.
2. Initialize COGNITRONICS Message Group Switches.
3. Initialize Glide Path Performance Categories.
4. Initialize Engine Flame-Out Switches.
5. Initialize Timer Switches.
6. Initialize COGNITRONICS Message Sequence Numbers.
7. Initialize Exercise Termination Code.
8. Convert Runway Orientation to COGNITRONICS Addresses.

9. Convert Wind Direction and Speed to COGNITRONICS Addresses.

10. Initialize Glide Path Dynamics Parameters.

11. Initialize Controller Program COGNITRONICS Output Queue.

12. Initialize PAB, PGCA and IDIIOM 1st Time Switches.

H. 2. 4. 3 Description. In addition to fulfilling the initialization requirements listed above, the GCIN program module contains the CLRDISP subroutine. The CLRDISP subroutine is an initialization routine used to clear the IDIIOM glide path display list of any aircraft position data from the previous run. It is not executed in the GCIN program itself, but rather in the PGCA program. This design feature allows retention of the previous GCA glide path display data for as long a period as possible.

H. 2. 5 Program Module Name

Pre-GCA Configuration Check (PGCA)

H. 2. 5. 1 Purpose. The purpose of PGCA is to monitor the subjects actions from the time the aircraft is airborne until the GCA approach is started.

H. 2. 5. 2 Requirements. PGCA is required to:

1. Output climbout instructions via COGNITRONICS.

2. Check the aircraft for proper GCA approach configuration.

3. Output GCA Controller Initialization messages via the COGNITRONICS.

4. Activate the proper GCA Exercise monitoring program modules at the proper time frames.

5. Provide re-entry for next GCA approach when required.

H. 2. 5. 3 <u>Description.</u> The Pre-GCA program module was designed to monitor the cockpit inputs and aircraft performance from the time the aircraft is airborne until the start of the GCA approach. It consists of the following phases:

1. Phase 0 - Upon entry, the program issues the appropriate climbout instructions via the COGNITRONICS and immediately advances to phase 1.

2. Phase 1 - This is the Pre-GCA approach configuration check phase. First, the updated difficulty factors are selected and stored for the AMOD program module. The program then checks the following aircraft parameters to insure that the aircraft is in a satisfactory configuration for a GCA approach:

   a. Landing Gear Down.

   b. Flaps in Full Position.

   c. Speed Brake In.

   d. Angle of Attack between 15.0 and 21.2 units.

   e. Altitude between 2400' and 2600'.

   f. Heading = Runway Orientation ± 5°.

   If, after 1 minute from the issuance of climbout instructions the above configuration has not been attained, the message 'CHECK LANDING SETTINGS' is sent via the COGNITRONICS and the message 'LANDING CHECK-LIST NOT COMPLETE' is printed on the typewriter. Each 30 second period thereafter, if the aircraft is still not in the proper GCA approach configuration, the COGNITRONICS message is repeated and one or more of the following messages is printed on the typewriter:

   a. CHECK WHEELS UP

   b. CHECK FLAP POSITION

   c. CHECK SPEED BRAKE OUT

   d. A/C AOA OUT OF LIMITS

e. A/C ALTITUDE OUT OF LIMITS

f. A/C HEADING OUT OF LIMITS

Because of the limited COGNITRONICS vocabulary, it was not possible to implement the above messages for voice output.

Once the proper GCA approach configuration has been attained, the IDIIOM glide path display is re-initialized (CLRDISP subroutine) and the program advances to phase 2.

3. Phase 2 - This phase outputs to the COGNITRONICS the GCA Controller Initialization messages and then advances to phase 3.

4. Phase 3 - This phase checks for the completion of the GCA Controller Initialization messages. When this has been accomplished, the last GCA Controller message is output to the COGNITRONICS, the message 'START GCA APPROACH' is sent to the typewriter, the GLIDE Path Dynamics (GPD), IDIIOM Display List Update (IDI) and Timer (TIMR) programs are activated and the program advances to phase 4.

5. Phase 4 - This phase waits for the completion of the final GCA Controller message and then starts actual GCA Control by activating the CONT:1 program. At this point, the run and session numbers are output to the line printer and the PGCA program is deactivated.

6. Phase 5 - This phase is used for re-entry to the GCA approach after completion of the first and subsequent runs of each session. It essentially is a 30 second wait phase to allow the pilot and aircraft to become stabilized before proceeding to the next run. At the end of this phase, control is transferred back to Phase 1. This phase is not entered if the previous run was the last of a session or an aircraft 'CRASH' condition occurred.

H. 2. 6 Program Module Name

GCA Controller (CONT)

H. 2. 6. 1 Purpose. The purpose of this program is to simulate the GCA Controller.

H. 2. 6. 2 Requirements. CONT is required to:

1. Monitor the aircraft position relative to the glide path.

2. Issue 'wave-off' instructions and terminate run if the aircraft strays outside of the pre-determined glide path limits.

3. Terminate run if aircraft has successfully penetrated touchdown "GATE".

4. Determine vertical and lateral aircraft displacements from the glide path.

5. Compute desired heading corrections to bring aircraft back to glide path centerline.

6. Determine appropriate vertical, lateral, distance or general information control messages for COGNITRONICS in order of priority.

7. Sample glide path variance parameters at selected intervals.

H. 2. 6. 3 Description. The CONT program module is composed of the following major sections:

1. Approach Monitor Section. This section determines if the aircraft has either strayed outside the predetermined glide path limits or has penetrated successfully the touchdown 'GATE'. If either condition has been attained, the run is terminated - the former by the issuance of a wave-off and the latter by a run completion message. A check of both the lateral and vertical displacement of the aircraft relative to the wave-off limits is made (See Figures 16 and 17) and if outside the limits the 'EXECUTE MISSED APPROACH' message is sent to the COGNITRONICS and the run is terminated.

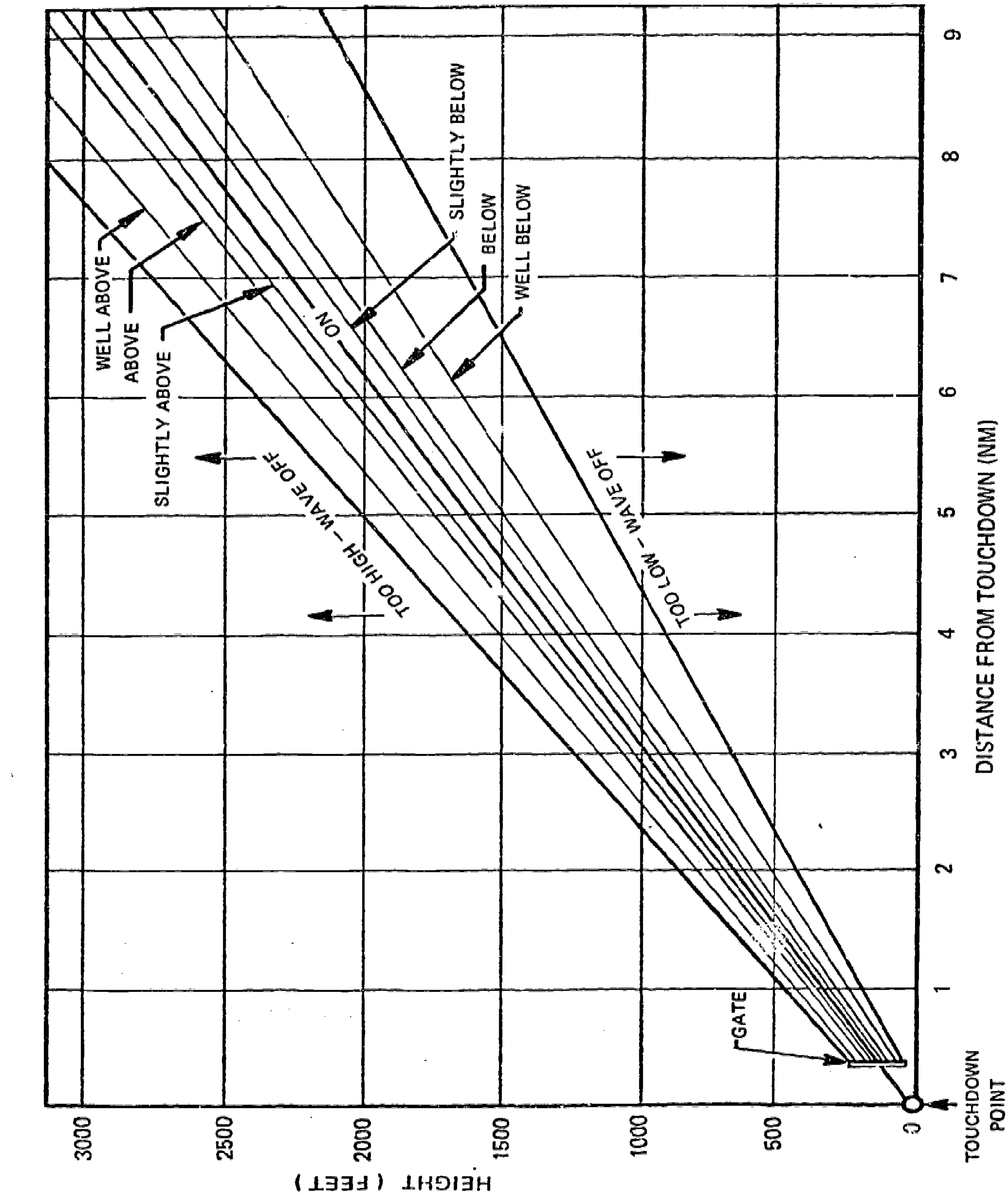


Figure 16. Controller Vertical Glide Path Geometry

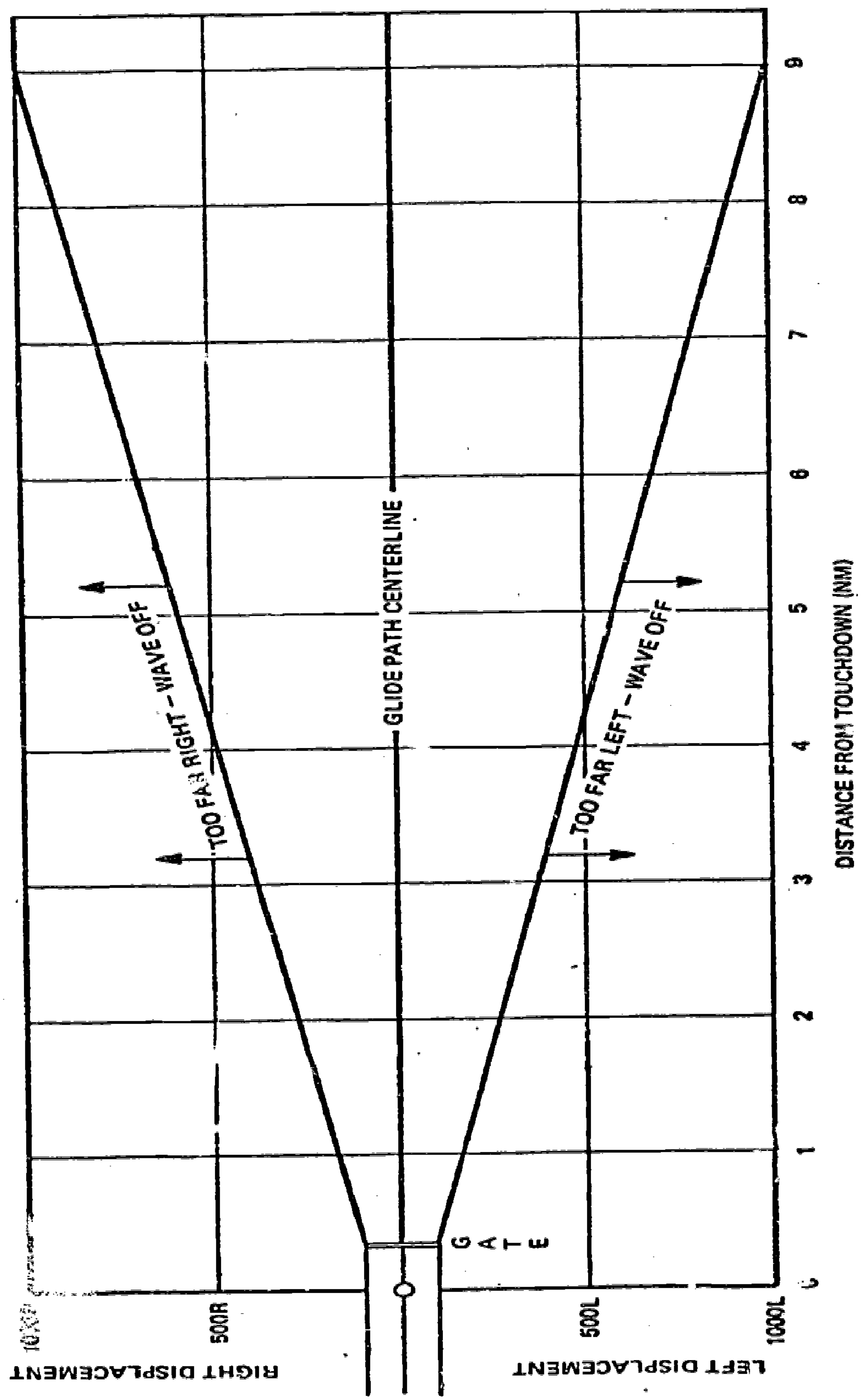


Figure 17. Controller Lateral Glide Path Geometry

A check is also made in this section to see if the aircraft has penetrated the touchdown 'GATE' and if so, the 'OVER TOUCHDOWN' message is sent to the COGNITRONICS. This condition indicates a successful completion of the GCA approach and the run is terminated.

Termination of the run by either of the above conditions results in the deactivation of all Controller associated programs (GPD, TIMR, CONT, EMRP) and the activation of the Exercise Termination (EXTR) program module.

If neither of the above conditions are satisfied, CONT interrogates the COGNITRONICS message queue for presence of a controller message. If one is already awaiting output, the remainder of CONT is bypassed.

2. Vertical Control Section - The aircrafts vertical displacement from the glide path is monitored from the time CONT is activated until the time either a wave off is issued or the 'GATE' is penetrated. Figure 16 depicts the vertical glide path geometry utilized in determining the appropriate vertical control message to select.

The current COGNITRONICS vocabulary precludes giving consistent rate information to the pilot concerning the vertical position of the aircraft from the glide path. The vertical position messages are, by necessity, therefore limited to the following set:

a. Well Above Glide Path.

b. Above Glide Path.

c. Slightly Above Glide Path.

d. On Glide Path.

e. Slightly Below Glide Path.

f. Below Glide Path.

g. Well Below Glide Path.

The boundaries between the above limits are defined by:

$$|ZLIM(I)| = KZLIM(I) + (KZ(I)) * (X_{GP})$$

where:

KZLIM(I) and KZ(I) are predetermined constants
X_{GP} is the distance from touchdown (NM)

ZLIM (0) is the boundary between 'ON GLIDE PATH' and 'SLIGHTLY ABOVE (BELOW) GLIDE PATH' error ranges:

$$|ZLIM(0)| = KZLIM\ (0) + (KZ(0)) * (X_{GP})$$

ZLIM (1) is the boundary between 'SLIGHTLY ABOVE (BELOW) GLIDE PATH' and 'ABOVE (BELOW) GLIDE PATH' error ranges:

$$|ZLIM\ (1)| = KZLIM\ (1) + (KZ\ (1)) * (X_{GP})$$

ZLIM (2) is the boundary between 'ABOVE (BELOW) GLIDE PATH' and 'WELL ABOVE (BELOW) GLIDE PATH' error ranges:

$$|ZLIM\ (2)| = KZLIM\ (2) + (KZ\ (2)) * (X_{GP})$$

ZLIM (3) is the boundary between 'WELL ABOVE (BELOW) GLIDE PATH' and wave-off error ranges:

$$|ZLIM\ (3)| = KZLIM\ (3) + (KZ\ (3)) * (X_{GP})$$

Preliminary testing of the system indicated the following constants to be most acceptable for the boundary conditions:

KZLIM (0) = 5'	KZ (0) = 10'/NM
KZLIM (1) = 10'	KZ (1) = 20'/NM
KZLIM (2) = 20'	KZ (2) = 40'/NM
KZLIM (3) = 40'	KZ (3) = 80'/NM

The glide slope angle was chosen as:

$$\alpha_{GP} = \tan^{-1} \frac{2500'}{8\ NM} = 2^{o}\ 54.4'$$

which represents the aircraft position at the start of the GCA control (8 NM) from touchdown at an altitude of 2500'.

A comparison is made of the aircrafts present vertical displacement from the glide path (Z_{GP}) and the KZLIM's. The appropriate message is selected and saved in a message queue (PQUEUE) according to its priority. Priority is based upon displacement - the greater the displacement, the higher the priority.

At this point, if the GPSTIME timer so indicates, a sample of the vertical glide path variance and angle of attack is made and saved for post-run data processing. Vertical glide path variance is scored by simply incrementing a counter for one of the 7 glide path message categories (WELL ABOVE, ABOVE, ETC) Angle of attack is sampled and placed in one of the following categories:

$\alpha < 18.0$ UNITS	(VERY FAST)
$18.0 \le \alpha < 18.7$ UNITS	(FAST)
$18.7 \le \alpha < 19.7$ UNITS	(ON SPEED)
$19.7 \le \alpha < 20.4$ UNITS	(SLOW)
$20.4 \le \alpha$	(VERY SLOW)

3. Lateral Control Section - In the initialization routine (GCIN), the aircraft is placed directly on the glide path centerline. Any subsequent displacement from the centerline results from the pilot's deviation from the assigned heading (no cross wind is currently introduced) This section computes the lateral displacement from the glide path centerline and determines which of the following messages should be selected for output:

a. HEADING IS GOOD

b. CORRECT HEADING IS XXX

c. TURN RIGHT (LEFT), HEADING XXX

129

One of the above messages will be selected depending upon the magnitude of the heading correction, θ_c, to be applied to the present heading ψ_p. If the lateral displacement is outside the limits shown in Figure 17, a wave off is issued. The wave off boundaries are determined by:

$$|YWOL| = YWO + (KYWO) * (X_{GP})$$

Where:

YWO and KYWO are predetermined constants

X_{GP} is the distance from touchdown (NM)

Preliminary testing of the system indicated the following constants to be the most acceptable for the lateral wave off limits:

$$YWO = 100' \qquad KYWO = 100'/NM$$

Figure 18 illustrates the geometry for computation of heading parameters. The following equations for heading computations can thus be formulated:

$$\psi_E \approx (\dot{Y}_{GP}/\dot{X}_{GP}) \cdot 57^\circ$$

$$\theta_D \approx (Y_{GP}/X_{GP}) \cdot 57^\circ$$

$$\theta_s = (KD) \cdot (\theta_D) \qquad \text{where } KD = \frac{X_{GP}}{X_{GP} - X_{GPS}}$$

$$\theta_C = \psi_E - \theta_S$$

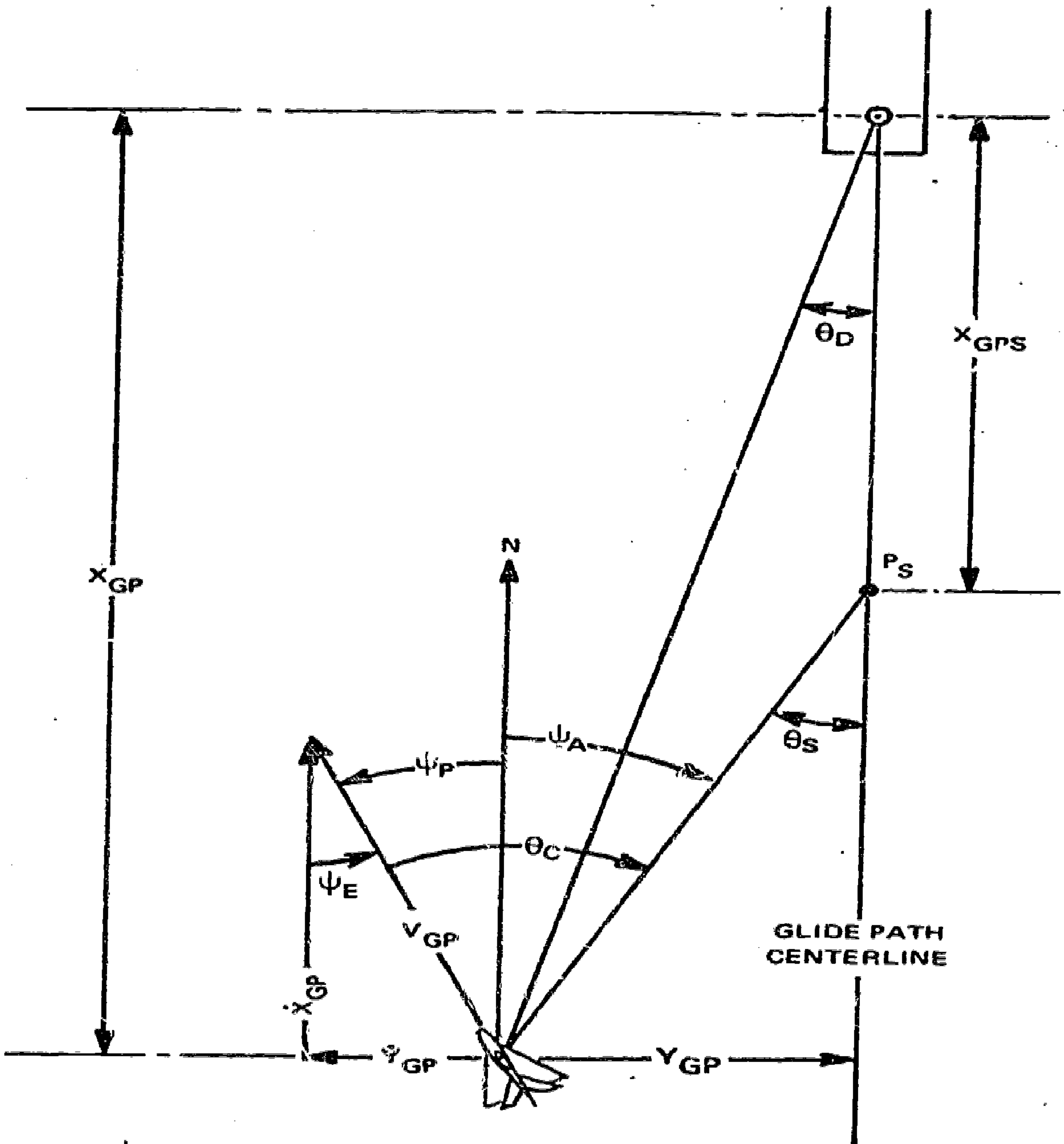
$$\psi_A = \psi_P + \theta_C$$

Where:

ψ_E = heading error

$\dot{X}_{GP}$ = forward aircraft velocity

130



ψ_A = New Assigned Heading
ψ_P = Present Heading
ψ_E = Present Heading Error
θ_D = Bearing of TD Point From A/C
θ_S = Course to Steer to Bring A/C Back to Centerline at $(1/_{KD})$ (X_{GP})
θ_C = Heading Correction
P_S = Glide Path Intercept Point
X_{GPS} = Distance of Intercept Point from Touchdown

Figure 18. Geometry of Heading Computation Parameters

$\dot{Y}_{GP}$ = lateral aircraft velocity

θ_D = Touchdown Point bearing

X_{GP} = distance from touchdown

Y_{GP} = distance to right of glide path

θ_S = course to steer to glide path intercep oint

θ_C = heading correction

ψ_A = new assigned heading

ψ_P = present heading

The intercept point in the program was arbitrarily set equal to 1/2 x GP resulting in $K_D = 2$.

In order to prevent erratic heading changes as the aircraft closes the touchdown point the program limits the heading corrections to 5 degrees when the distance to touchdown is less than 5 miles.

The selection of the appropriate heading message to be saved in the priority queue (PQUEUE) is based on the following criteria:

HEADING IS GOOD	$\lvert\theta_c\rvert \leq .5^\circ$
CORRECT HEADING IS XXX	$.5^\circ < \lvert\theta_c\rvert \leq 5^\circ$
TURN RIGHT (LEFT) HEADING XXX	$5^\circ < \lvert\theta_c\rvert$

As in the vertical control section, the messages representing the greatest correction ('TURN RIGHT (LEFT) HEADING XXX') have the highest priority.

4. Distance To Go Section - This section monitors the aircraft distance from touchdown and when certain criteria are met selects either the appropriate Distance-To-Go message, wind information message or runway information message for insertion into the priority queue (PQUEUE)

5. Output Message Selection Section - This section is a logic routine to select the most appropriate message from the priority (PQUEUE) for output to the COGNITRONICS. Selection is based upon the minimization of message redundancy as well as message priority.

H. 2. 7 Program Module Name

Emergency Procedure Processor (EMRP)

H. 2. 7. 1 Purpose. The purpose of EMRP is to monitor and control the Emergency Procedures Exercise of the ATE program.

H. 2. 7. 2 Requirements. When the Emergency Procedures Exercise has been activated by the ATE Program, EMRP is required to:

1. Initialize the engine failure and communications failure parameters.

2. Halt COGNITRONICS output at the prescribed distance from touchdown, if communications failure has been directed.

3. Flame out the right (left) engine at the prescribed distance from touchdown, if engine failure has been directed.

4. Monitor and record the subjects responses to either emergency.

5. Terminate the exercise upon either successful completion of the required subject responses or upon expiration of a predetermined time period.

H. 2. 7. 3 Description. The emergency procedures were designed to be implemented during the GCA approach. Currently, two emergency procedures are incorporated in the ATE Emergency Procedures Exercise - (1) Communications Failure, and (2) Engine Failure. A series of five emergency runs are included in the ATE curriculum, after the successful completion of the GCA exercise.

It is possible, however, to induce an emergency procedure by input through the typewriter. This is done by selecting the desired level for the EMR EXERCISE (See ATE Operating Instruction, Appendix A). EMR selects the Emergency Procedures Exercise and the value for level indicates the parameters to be employed. The SIGMA-7 word format for the level (parameters) is as follows:

E	L/R	C	DF

where:

E indicates engine failure

$E = 0$; no engine failure this run

$E \neq 0$; number of whole nautical miles from touchdown at which engine failure is to occur

L/R indicates which engine is to flame-out

$L/R = 0$; Left engine flame-out

$L/R = 1$; Right engine flame-out

C indicates communications failure

$C = 0$; no communications failure this run

$C \neq 0$; number of whole nautical miles from touchdown at which communications failure is to occur

DF indicates the GCA difficulty factors and levels table value (1-5) to be employed throughout this run.

Example: If the following were input via the keyboard:

$EXER   EMR = 3124

the ATE program would be directed to:

1. Implement flame-out of the right engine when the aircraft was 3 NM from the touchdown point.

2. Implement communications failure (COGNITRONICS stoppage) when the aircraft was 2 NM from the touchdown point.

3. Select the 4th table value for the GCA difficulty factors and levels to be employed during this run. (DGCATAB is in the ALOG program module.)

The 5 emergencies currently employed in the ATE Emergency Procedures Exercise are (in sequence):

1. EMR = 0041 - communications failure 4 miles from touchdown. GCA difficulty level = 331 (1st table value)

2. EMR = 3032 - communications and left engine flame-out 3 miles from touchdown. GCA difficulty level = 332 (2nd table value)

3. EMR = 4123 - Right engine flame-out 4 miles from touchdown and communications failure 2 miles from touchdown. GCA difficulty level = 332 (3rd table value)

4. EMR = 5004 - Left engine flame-out 5 miles from touchdown. GCA difficulty level = 343 (4th table value)

5. EMR = 3105 - Right engine flame-out 3 miles from touchdown. GCA difficulty level = 343 (5th table value)

Decoding of the emergency is done in the ALOG program module but implementation is performed in this program. In the event of communications failure during the GCA approach (no transmission received for 5 seconds) the subject is expected to implement wave-off procedures turn to a course 180° from the runway orientation and climb to 2500' altitude. At this point communications will be restored and further instructions given.

In the event of engine failure, the subject is expected to continue the GCA approach with one engine until either the approach has been completed, a wave-off is issued or communications failure occurs. In the latter event, the communications failure procedure described above should be followed. The program prohibits re-start of the failed engine until:

1. the approach has been completed, or
2. a wave-off is issued, or
3. completion of communications failure response, if applicable.

Normal procedures for an air-start of the affected engine can then be employed.

H. 2. 8 Program Module Name

Data Processing (DATP)

H. 2. 8. 1 Purpose. The purpose of DATP is to perform the post-run data processing.

H. 2. 8. 2 Requirements. DATP is required to process and output to the line printer:

1. Run general information
2. Vertical glide path variance data
3. Lateral glide path variance data
4. Angle of Attack variance data
5. Path Data
6. Gate Data
7. Path Score

8. Gate Score, if any

9. Adjusted Patch Score, if any

10. Total Gate Score

11. Emergency Procedure Response Data

H. 2. 8. 3 Description. Figure 19 is an example of the printout resulting from the post-run data processing of an Emergency Procedures run. A right engine flame-out was given at four miles from touchdown and a communications failure implemented at 2 miles from touchdown (LEVEL = 4123). The glide path variance data (Vertical, Lateral, Angle of Attack) sampled during the run (CONT program module) is categorized and the percent of total for each category is computed and printed. The following scores are then computed:

1. PATH SCORE - This score is computed for each run. It can be expressed in the following form:

$$P_S = \frac{V_S + H_S + \alpha_S}{3} + T_S$$

where:

V_S = % (OGP) + 1/2 (% (SAGP) + % (SBGP))

% (OGP) = % of samples 'ON GLIDE PATH'.

% (SAGP) = % of samples 'SLIGHTLY ABOVE GLIDE PATH'.

% (SBGP) = % of samples 'SLIGHTLY BELOW GLIDE PATH'

H_S = % (HC ≤ . 5) + 1/2 (% (. 5<HC≤5))

% (HC ≤ . 5) = % samples heading correction is less than or equal to . 5°.

% (. 5<HC≤5) = % of samples heading correction is greater than . 5° but less than or equal to 5°.

```
NAME    SMITH       DATE    11/17/70

    RUN NUMBER  0001      EXERCISE  EMR     LEVEL   4123    SESSION 0004

    RUN TERMINATED BY   SUCCESSFUL COMPLETION

    GLIDE PATH VARIANCE DATA    TOTAL NUMBER OF SAMPLES 129.0

      VERTICAL               WELL ABOVE     ABOVE     SLGT ABOVE     ON      SLGT BELOW    BELOW     WELL BELOW

        SAMPLE SIZE              0           9.0         9.0        74.0       37.0          0           0

        PERCENT OF TOTAL         0           6.976       6.976      57.364     28.682        0           0

      HORIZONTAL                       HC <.5 DEG         .5 DEG <HC <5 DEG               HC <5 DEG

        SAMPLE SIZE                       18.0                     99.0                     12.0

        PERCENT OF TOTAL                  13.953                   76.744                    9.302

      ANGLE OF ATTACK        VERY FAST     FAST       ON SPEED      SLOW      VERY SLOW

                               (0-18)   (18.1-18.6) (18.7-19.6) (19.7-20.3)  (20.4-30)

        SAMPLE SIZE              32.0       19.0        37.0        21.0        20.0

        PERCENT OF TOTAL         24.806     14.728      28.682      16.279      15.503

    PATH DATA       % OF PATH COMPLETED   80.020            TIME (SECONDS)     129.0

    SUMMARY         PATH SCORE        72.403         ADJUSTED PATH SCORE   137.958

                    GATE SCORE        NONE           TOTAL GATE SCORE      137.958

    EMERGENCY DATA     THROTTLE RESPONSE (SECONDS)   1.649       FLAP RESPONSE (SECONDS)   6.799

                       COMMUNICATIONS FAILURE RESPONSE (SECONDS)     84.750

    TOTAL NUMBER OF RUNS THIS FILE 0023

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

Figure 19. Example of Data Processing Printout

α_S = % (18.1 < AOA < 20.3) = % samples Angle of Attack is greater than 18.1 units but less than 20.3 units

T_S = 100 (ATERAF)
ATERAF = ATE Turbulence Factor (0 through .16)

2. ADJUSTED PATH SCORE - This score is computed whenever the aircraft fails to penetrate the landing threshold 'GATE' (wave-off, crash, communications failure, etc.) and is of the following form:

$$P_{SA} = L\,(PS) + 100L$$

where:

$$L = \frac{(X_{GPLIN} - K_{TDLIM} - X_{GP})}{X_{GPLIN}}$$ = proportion of glide path completed before wave-off.

X_{GPLIN} = Initial distance from touchdown

K_{TDLIM} = 'GATE' distance from touchdown

X_{GP} = Aircraft distance from touchdown at wave-off.

3. GATE SCORE - This score is computed any time the aircraft penetrates the landing threshold 'GATE' and can be expressed:

$$G_S = 1/3\,(Y_S + Z_S + A_S + \dot{\psi}_S + \dot{\alpha}_S)$$

where:

$$Y_S = 100 - |Y_E|$$

$|Y_E|$ = Absolute offset error at 'GATE' (feet)

$Z_S = 100 - Z_E$

Z_E = Absolute vertical error at 'GATE' (feet)

$A_S = 100 - 25\ (|\alpha - 19.2|)$

$|\alpha - 19.2|$ = Absolute Angel of Attack error at 'GATE' (units)

$\dot{\psi}_S = 25\ (\dot{\psi})$

$\dot{\psi}$ = rate of change of heading at 'GATE' (degrees/second)

$\dot{\alpha}_S = 25\ |\dot{\alpha}|$

$\dot{\alpha}$ = rate of change of Angle of Attack at 'GATE' (units/seconds)

4. TOTAL GATE SCORE - This score reflects the subjects performance for the entire run and is a combination of the Gate Score and Path Score. If the aircraft passed through the 'GATE', it is expressed as:

$$SCORE = P_S + G_S + 100$$

If the aircraft failed to penetrate the 'GATE', total gate score is merely the adjusted path score:

$$SCORE = P_{SA}$$

After the scores have been computed, the program processes the Emergency Procedures Response data if the run was an Emergency Procedures Exercise. Throttle response time, flap response time and communications failure response time are converted to EBCDIC for output to the line printer.

H. 2. 9 Program Module Name

Adaptive Logic (ALOG)

H. 2. 9. 1 Purpose. The purpose of ALOG is to select and implement the difficulty levels to be employed for the next run.

H. 2. 9. 2 Requirements. ALOG is required to:

1. Evaluate the subjects performance score for the current run and previous run, if any.

2. Determine the difficulty factor table increment.

3. Select and place in the STUDENT FILE the set of difficulty factors and levels to be employed on next run.

4. Decode difficulty levels and store the corresponding difficulty factors for subsequent insertion into the AMOD program.

H. 2. 9. 3 Description. The difficulty of subsequent runs is increased (decreased) depending upon the subject's performance during the past two runs. The difficulty factors currently employed for the GCA approach and Emergency Procedures Exercises are:

1. Wind Along the Runway.

2. Center of Gravity.

3. Turbulence.

Each of these difficulty factors are subdivided into the following five levels of difficulty:

1. Wind Along the Runway:

Level 1 - 30 knots of head wind

141

Level 2 15 knots of head wind

Level 3 2 knots of head wind

Level 4 15 knots of tail wind

Level 4 30 knots of tail wind

2. Center of Gravity:

Level 1 1000 pounds of internal fuel

Level 2 LEVEL 1 plus center tanks

Level 3 LEVEL 2 plus 2 wing tanks

Level 4 LEVEL 3 plus 2 sidewinder missiles

Level 5 LEVEL 4 plus 4 sparrow missiles

3. Turbulence:

Level 1 No turbulence

Level 2 4% of maximum turbulence

Level 3 8% of maximum turbulence

Level 4 12% of maximum turbulence

Level 5 16% of maximum turbulence

Combinations of the above difficulty levels are stored in the ALOGTAB table in the ALOG program (See Table 12) starting with the simplest task (LEVEL 111) and terminating with the most difficult task (LEVEL 555) Each trainee is started at the lowest sequence number and, depending upon his performance, the sequence number is incremented (decremented) by a value of +1 to +4 (-1 to -4) Sequence numbers cannot be incremented beyond the maximum value (38) or decremented below the minimum value (1) If an attempt is made to do this, the sequence number is automatically set to the highest (lowest) value for the next run. Sequence numbers are incremented (decremented) by a value determined upon the trainee's performance score on the current

TABLE 12. ALOGTAB DIFFICULTY LEVEL SEQUENCE

Sequence Number	Wind Level	C. G. Level	Turbulence Level
1	1	1	1
2	2	1	1
3	3	1	1
4	4	1	1
5	5	1	1
6	3	2	1
7	3	3	1
8	3	4	1
9	3	5	1
10	5	2	1
11	5	3	1
12	5	4	1
13	5	5	1
14	3	1	2
15	3	2	2
16	3	3	2
17	3	4	2
18	3	5	2
19	5	1	2
20	5	2	2
21	5	3	2
22	5	4	2
23	5	5	2
24	3	3	3
25	3	4	3
26	3	5	3
27	5	5	3
28	3	1	4
29	3	3	4
30	3	5	4
31	4	5	4
32	5	5	4
33	3	1	5
34	3	2	5
35	3	3	5
36	3	4	5
37	3	5	5
38	5	5	5

Previous Run's Sequence Number Increment Status	Score < 50	50 ≤ Score < 100	100 ≤ Score < 150	150 ≤ Score < 200	200 ≤ Score
- (Decremented)	-4	-2	0	+1	+3
0	-3	-1	0	+1	+3
+ (Incremented)	-3	-1	0	+2	+3

Figure 20. Difficulty Level Sequence Number Increment Logic

run and whether the sequence number was incremented (decremented) the previous run. Figure 20 illustrates the technique employed to select the sequence number increment.

The DFSELECT subroutine, although physically part of the ALOG program module, is called in the Exercise Scheduler (EXSC) program prior to the start of the next run. The DFSELECT Subroutine decodes the next difficulty level and selects the appropriate difficulty factors for subsequent use by the AMOD program.

APPENDIX I

PLOTS OF INDIVIDUAL PILOT PROGRESS

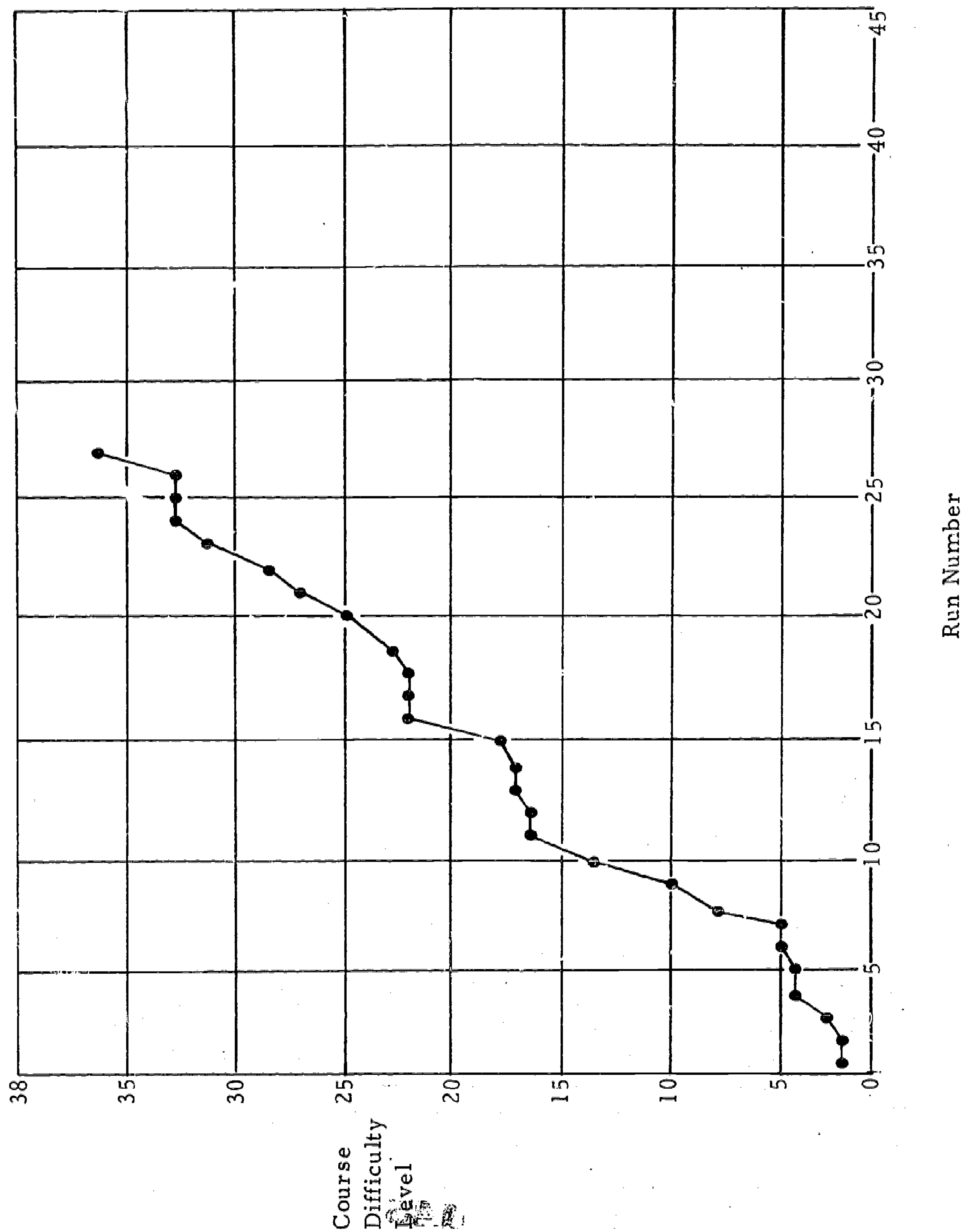


Figure 21. Plot of Runs by Pilot #1

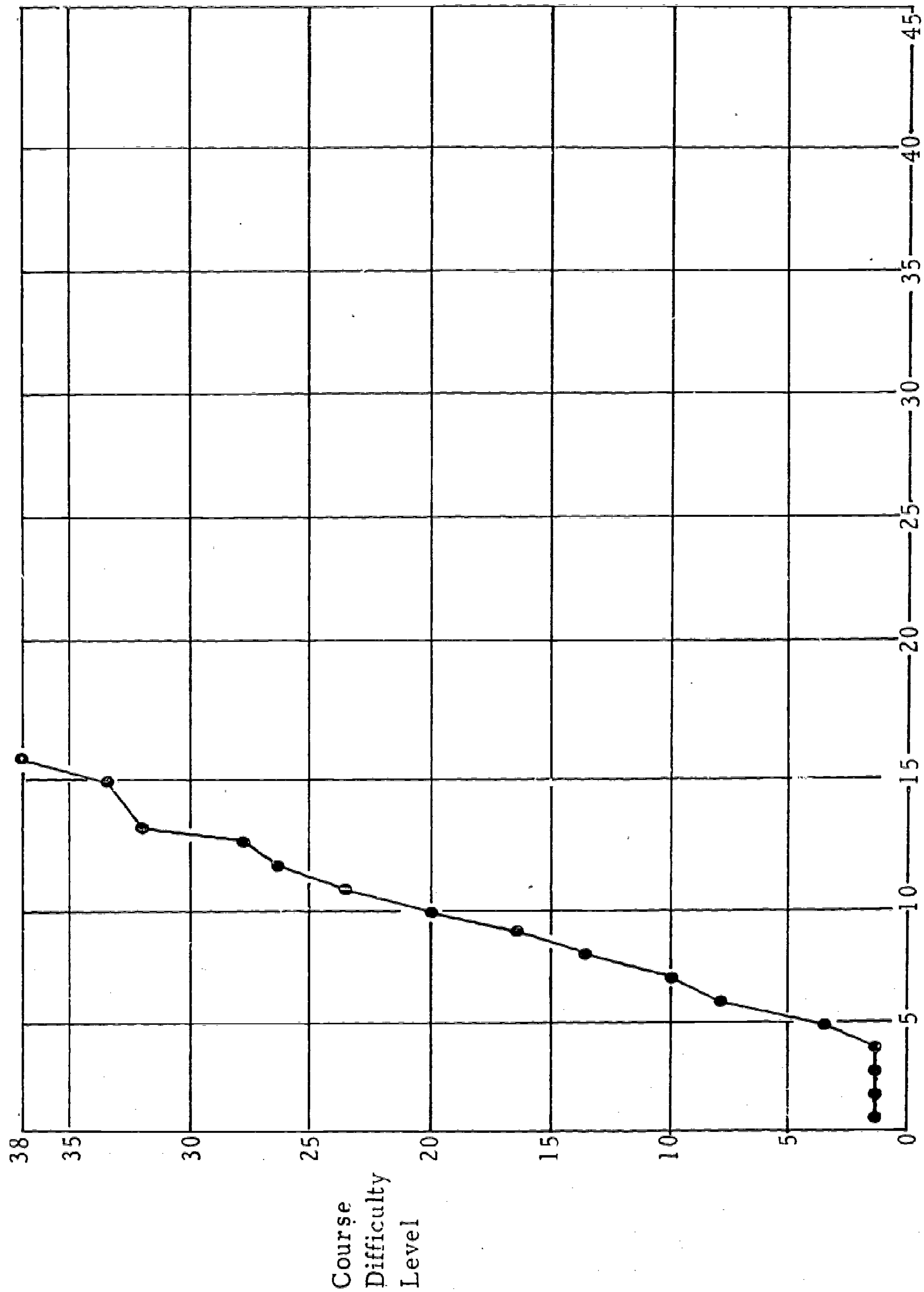


Figure 22. Plot of Runs by Pilot #2

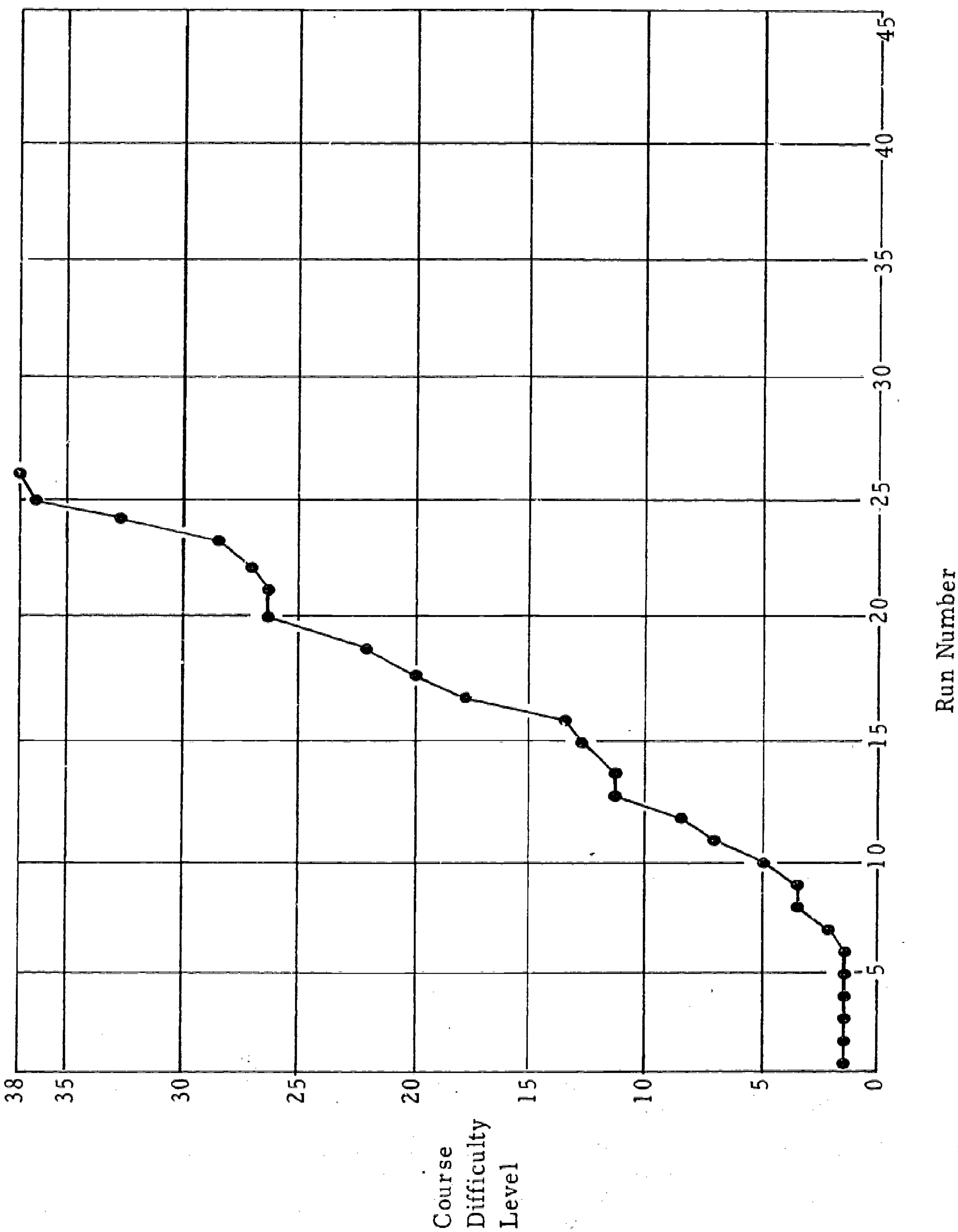


Figure 23. Plot of Runs by Pilot #3

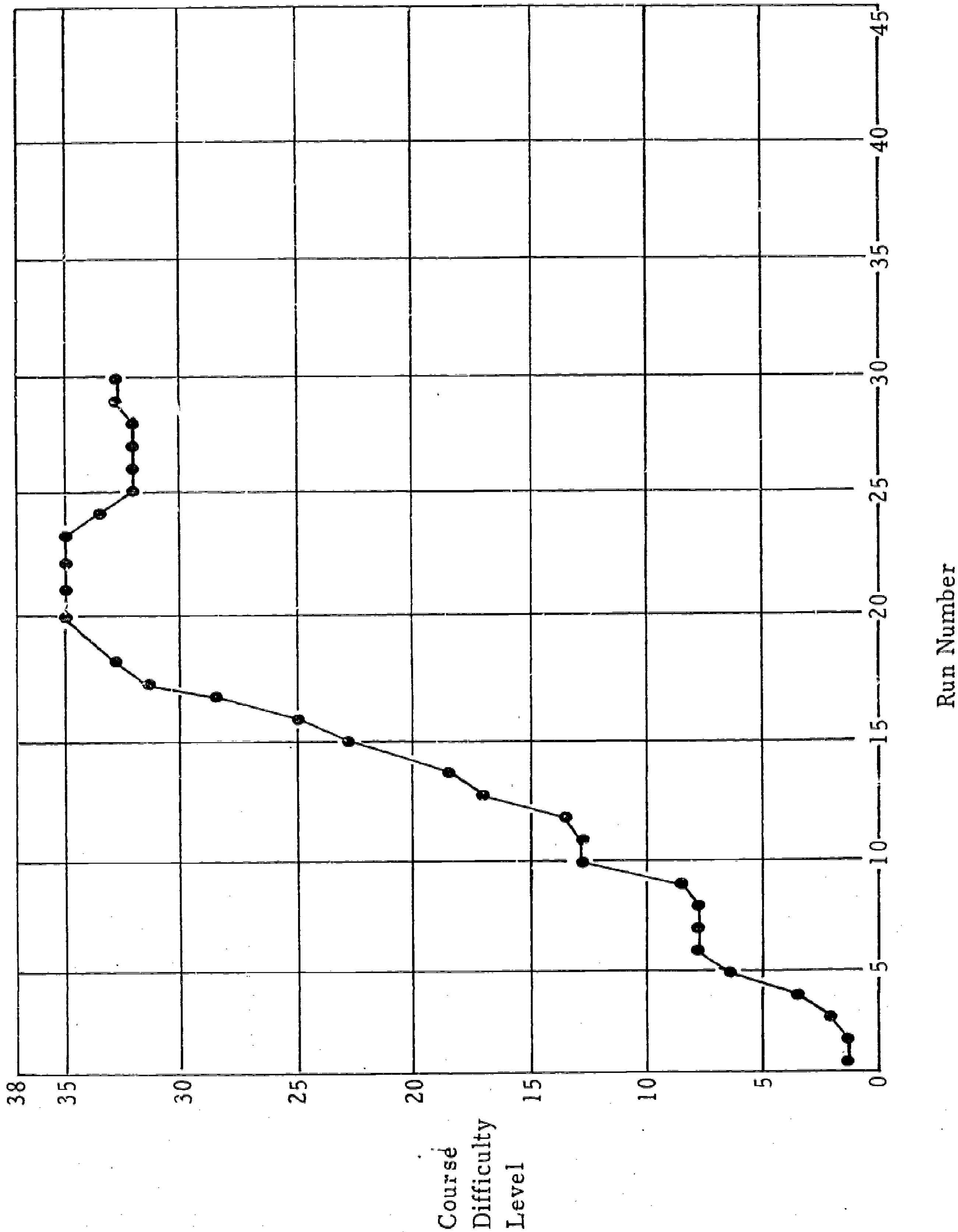


Figure 24. Plot of Runs by Pilot #4

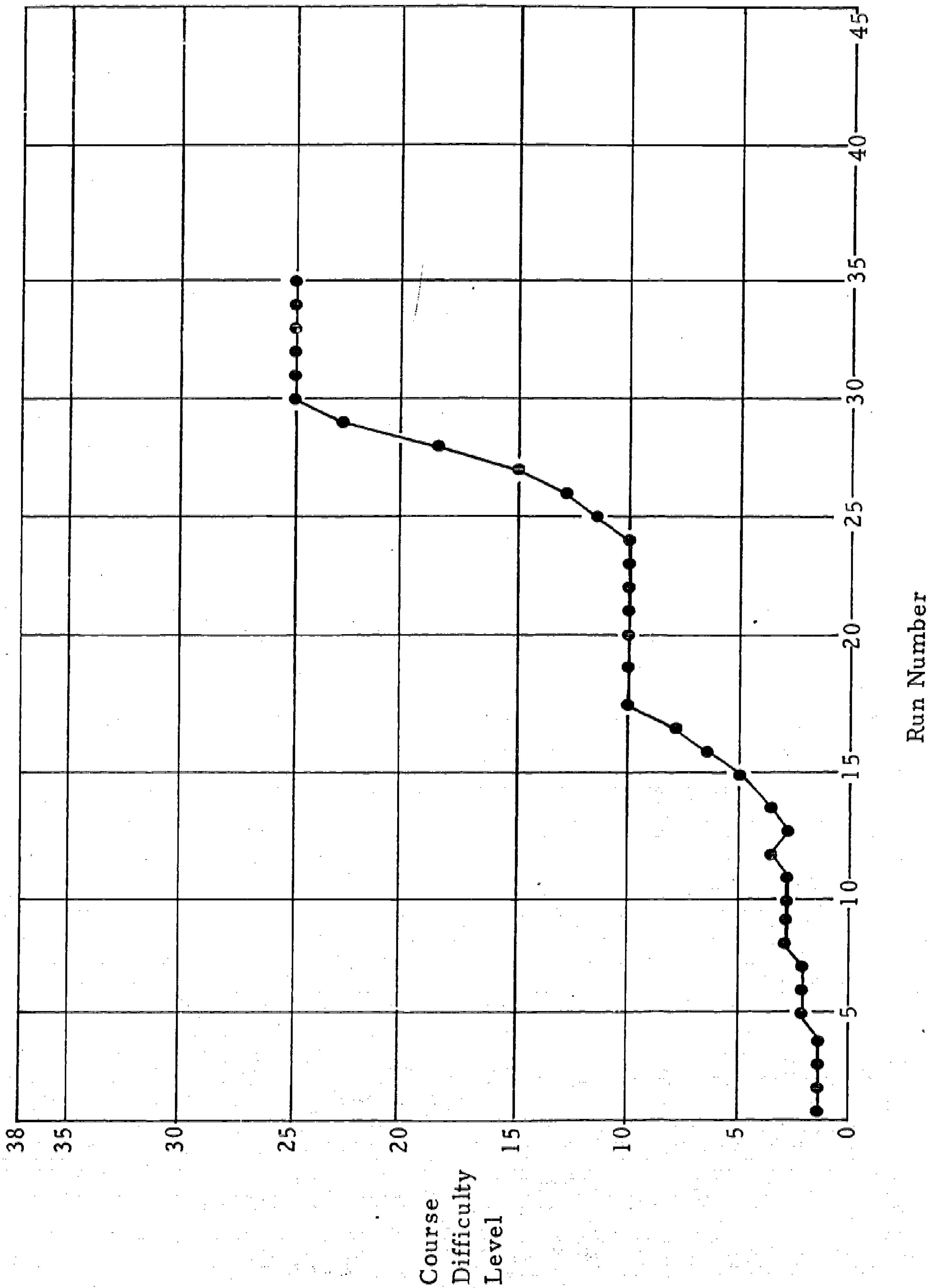


Figure 25. Plot of Runs by Pilot #5

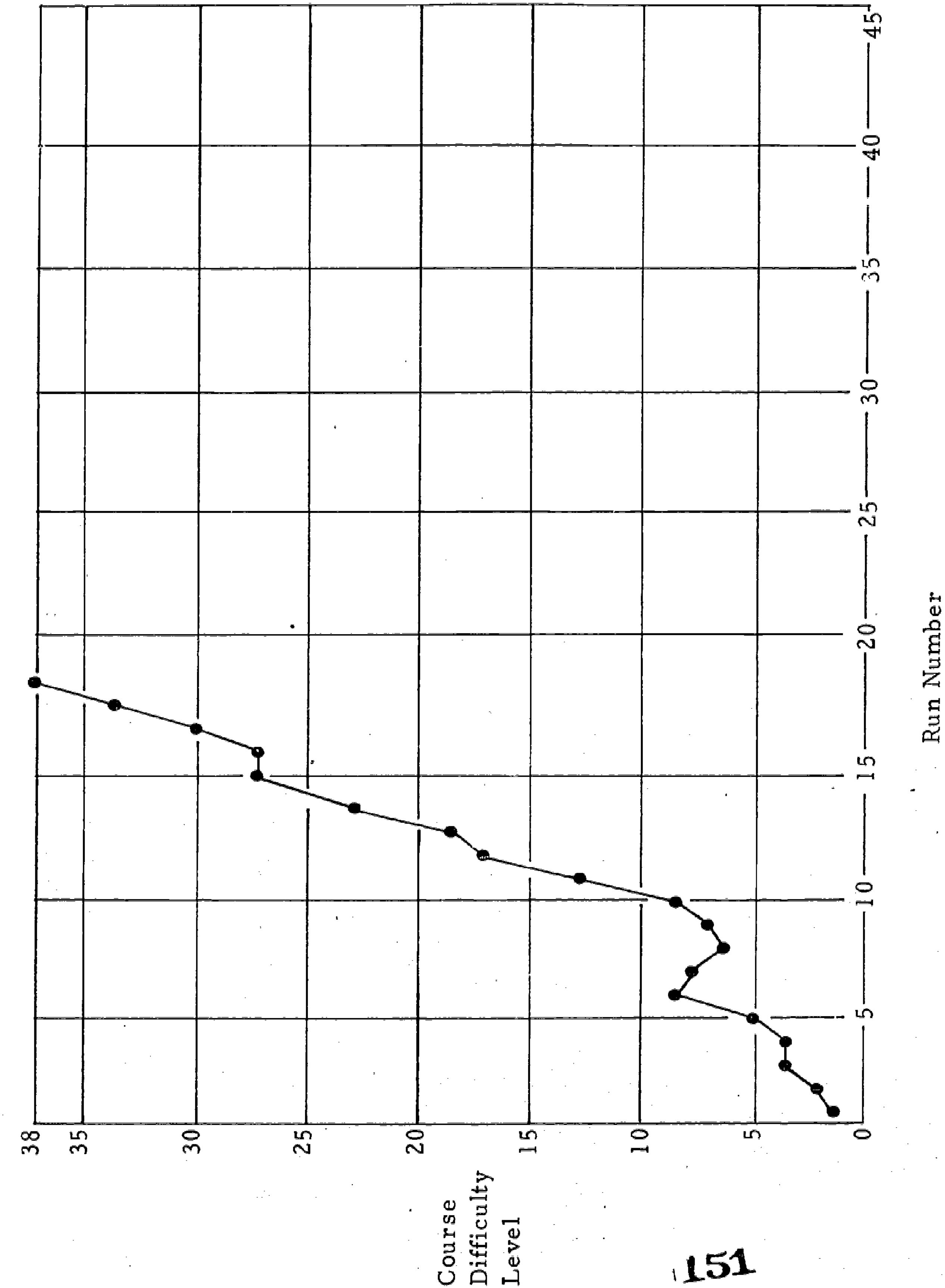


Figure 26. Plot of Runs by Pilot #6

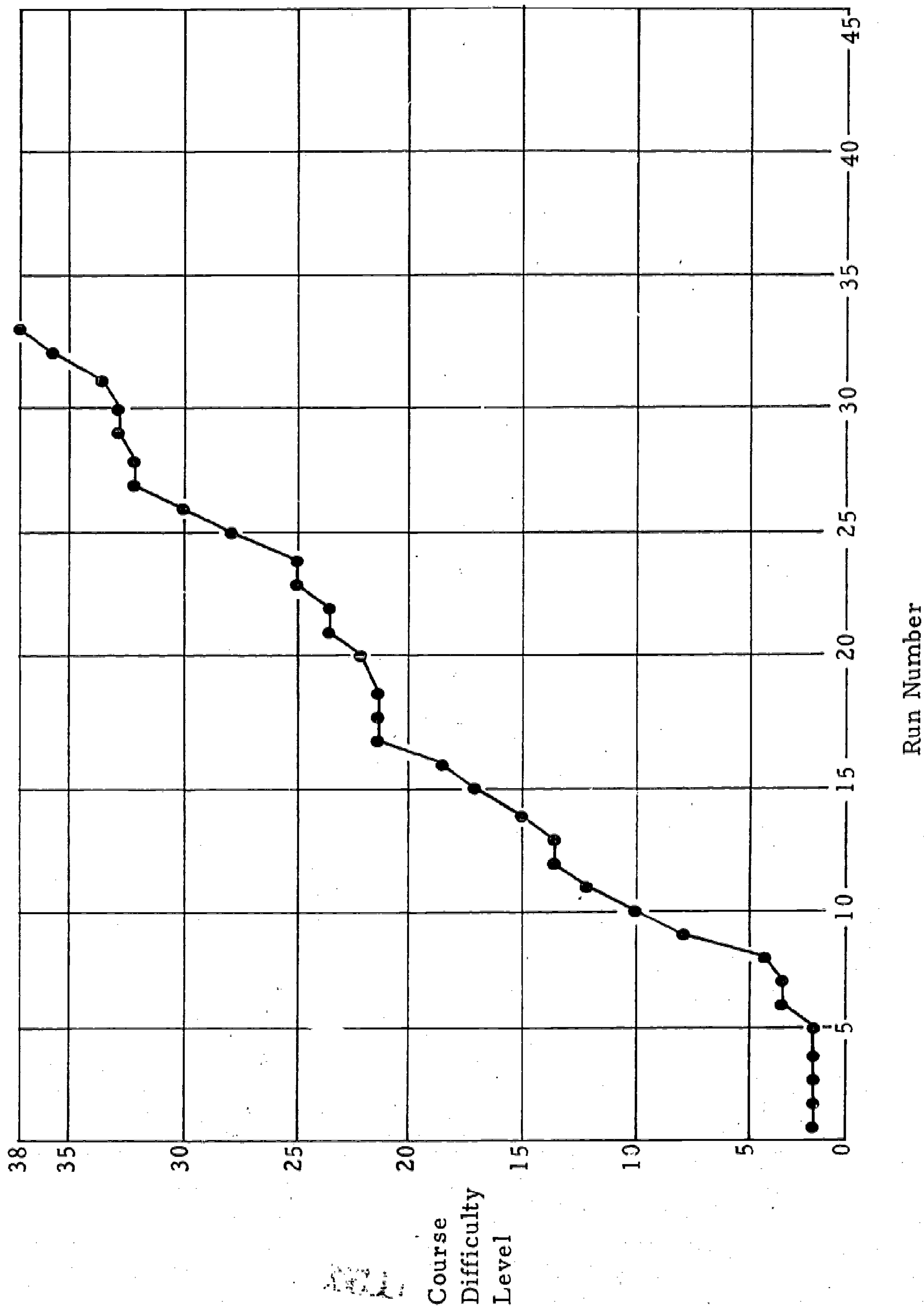


Figure 27. Plot of Runs by Pilot #7

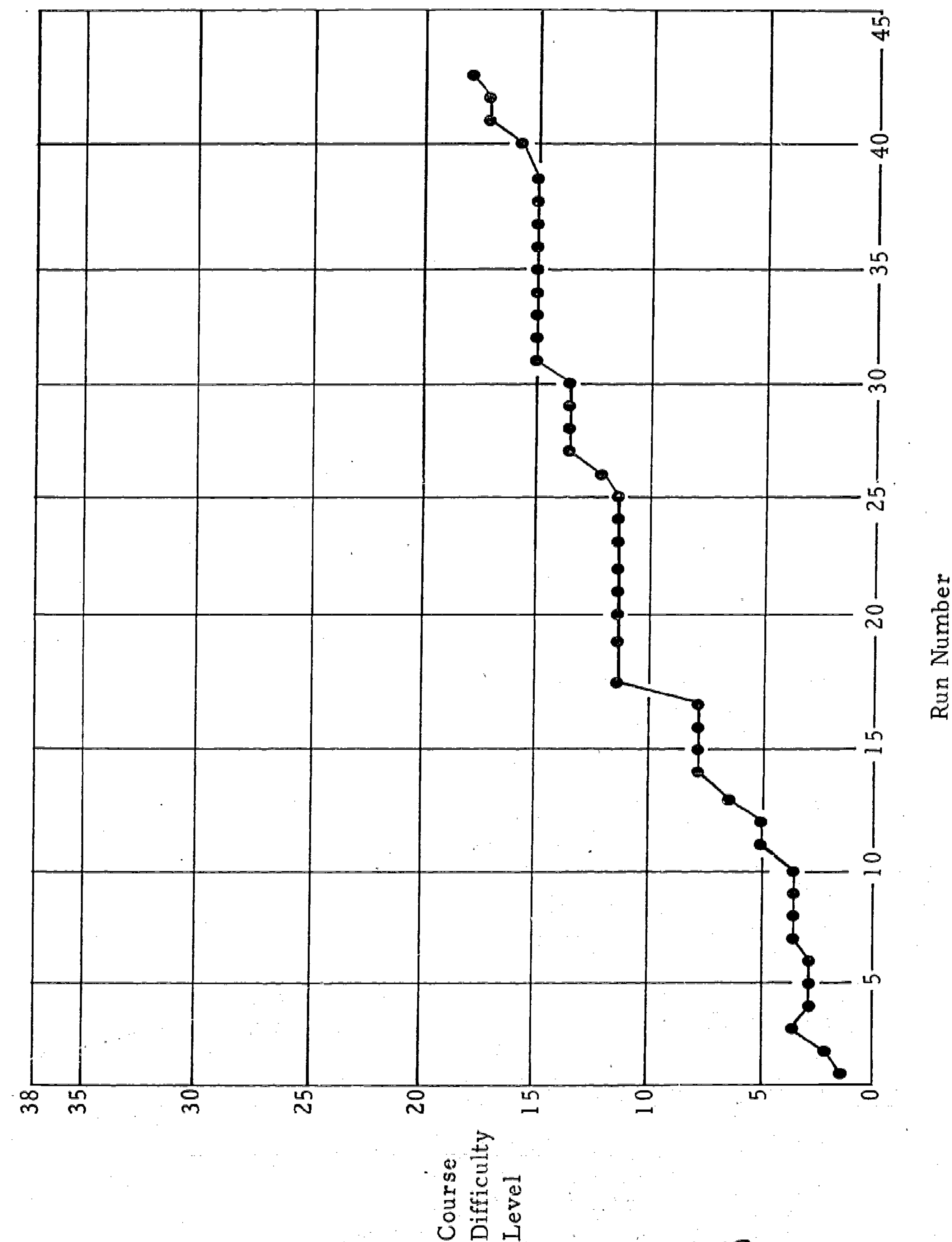


Figure 28. Plot of Runs by Pilot #8

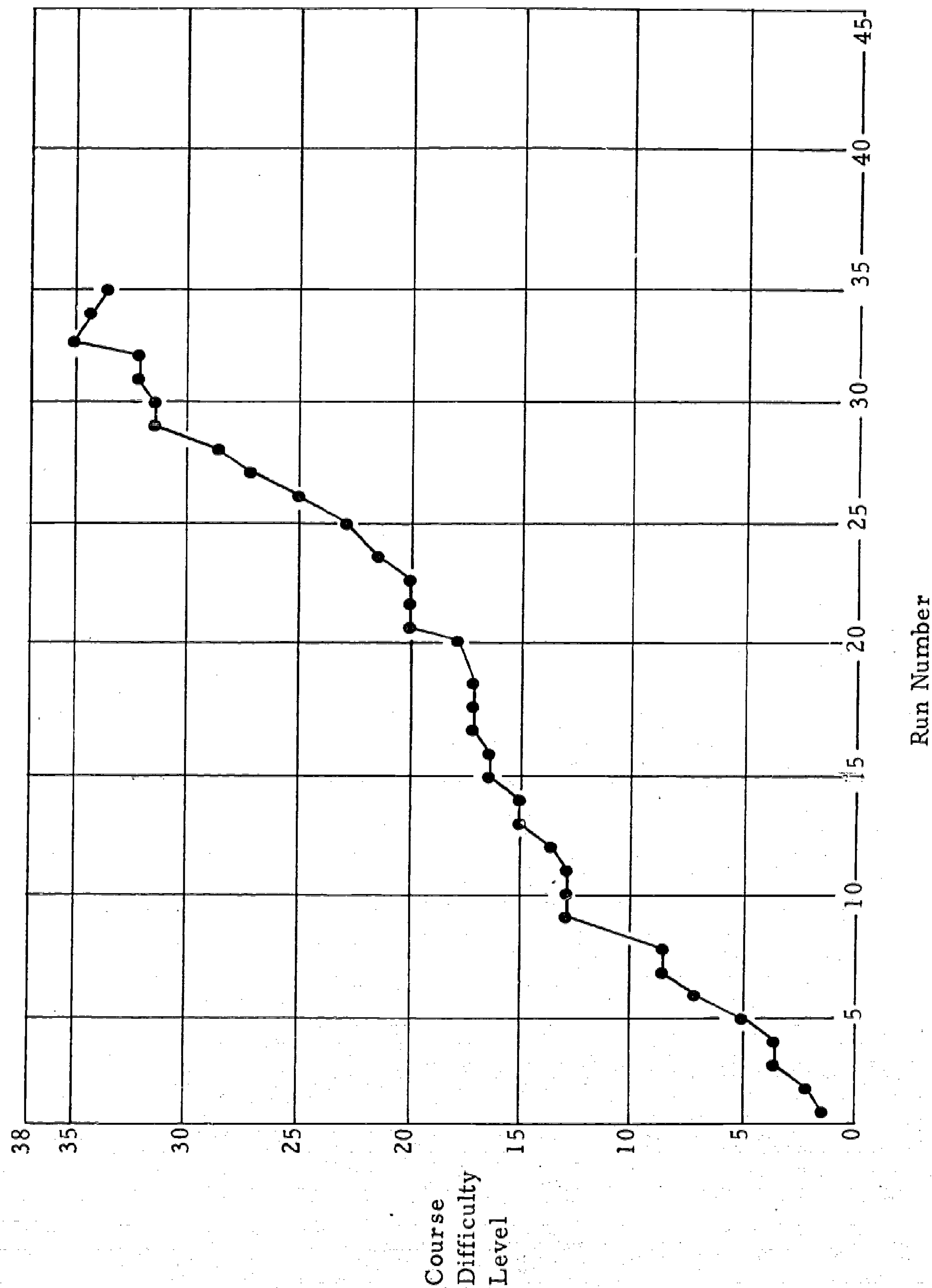


Figure 29. Plot of Runs by Pilot #9

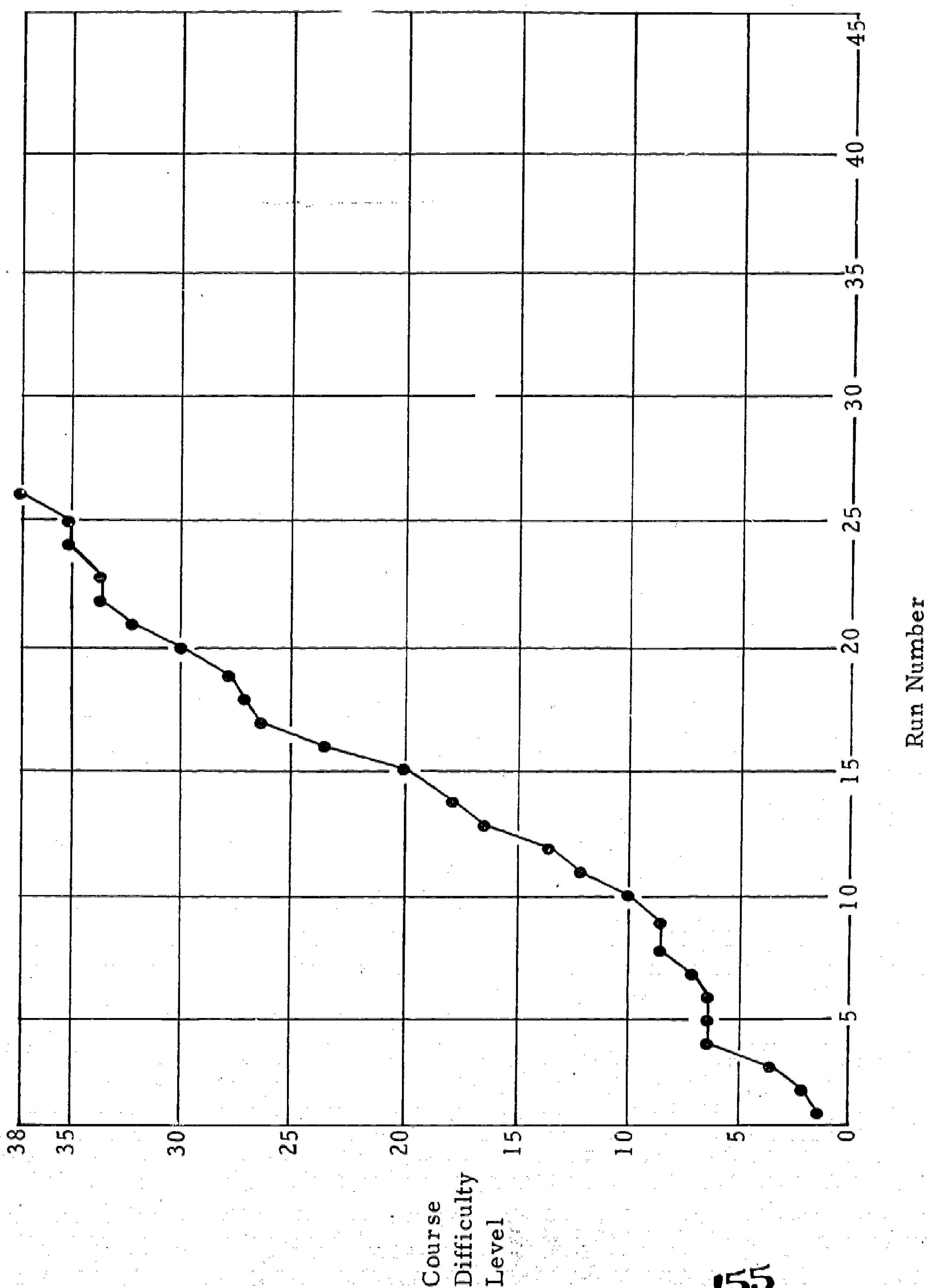


Figure 30. Plot of Runs by Pilot #10

155

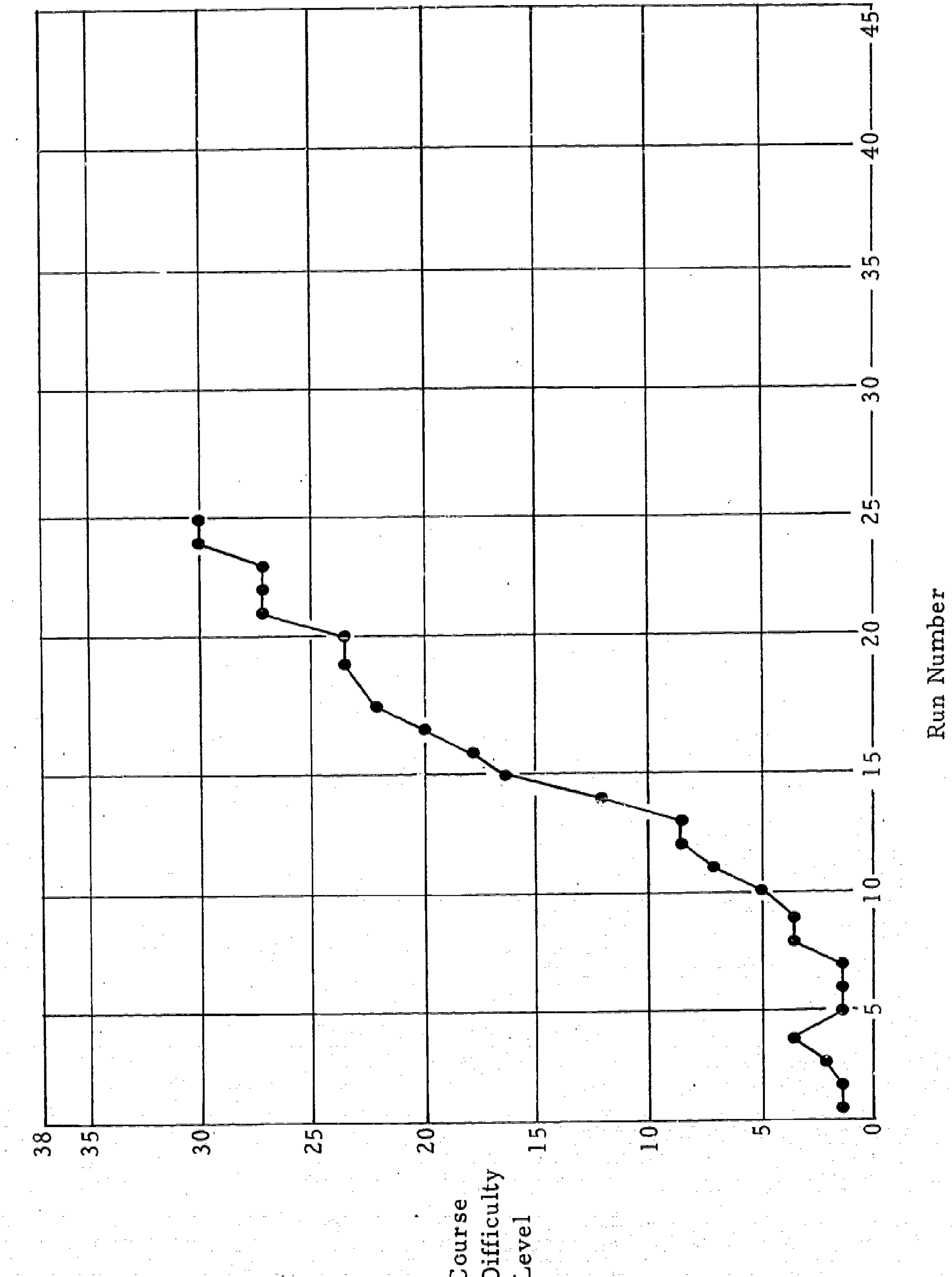


Figure 31. Plot of Runs by Pilot #11

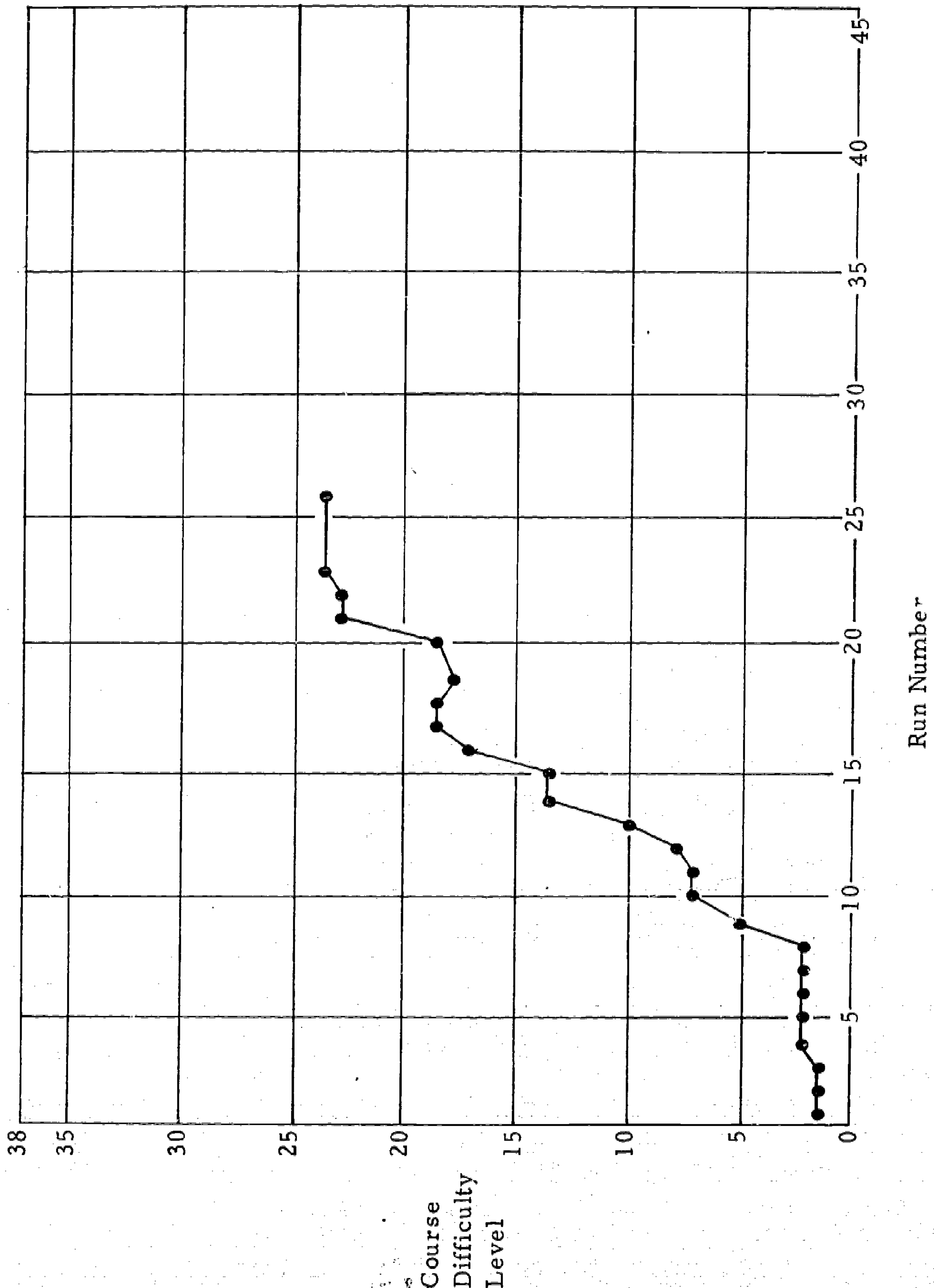


Figure 32. Plot of Runs by Pilot #12

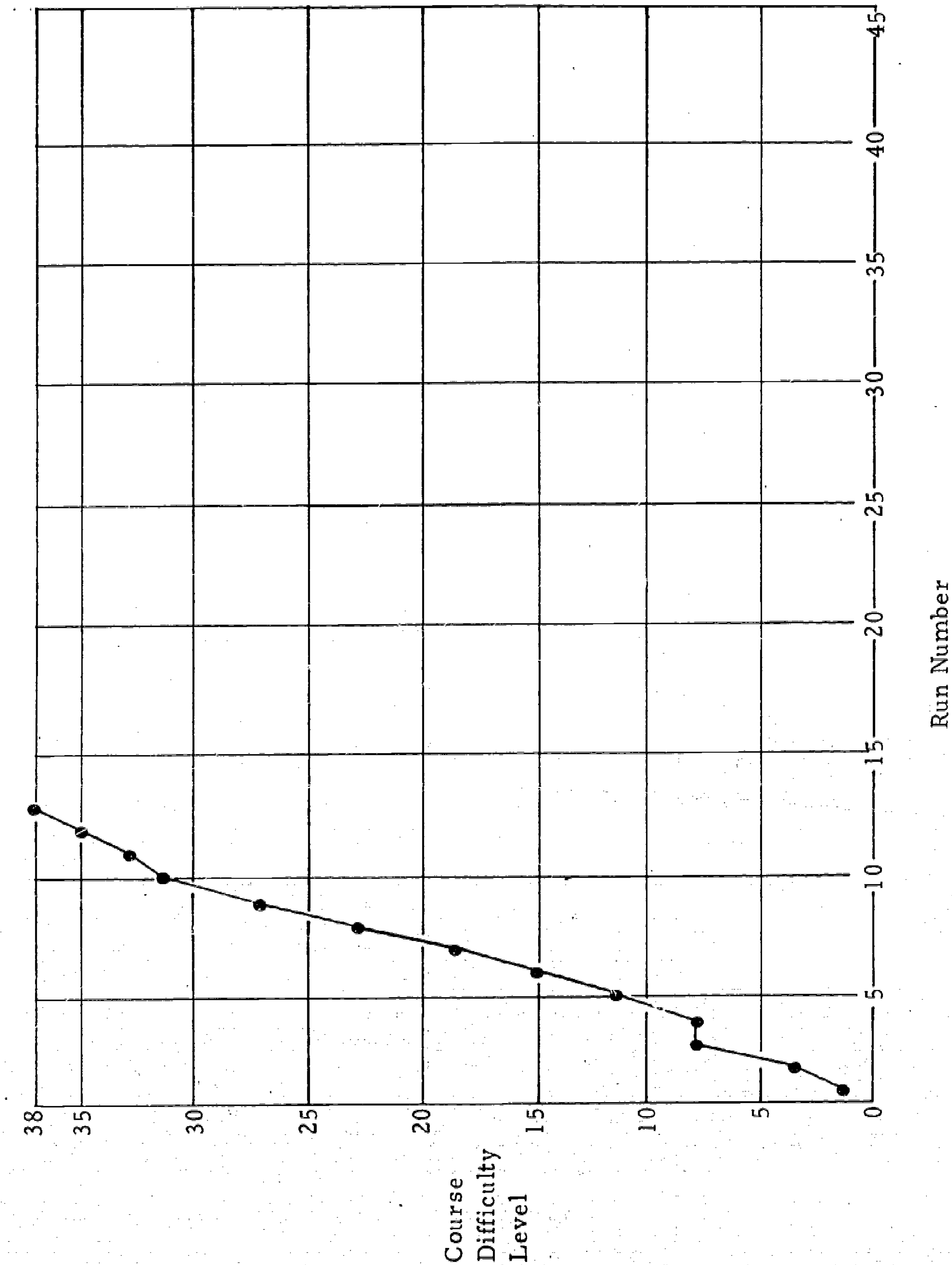


Figure 33. Plot of Runs by Technician

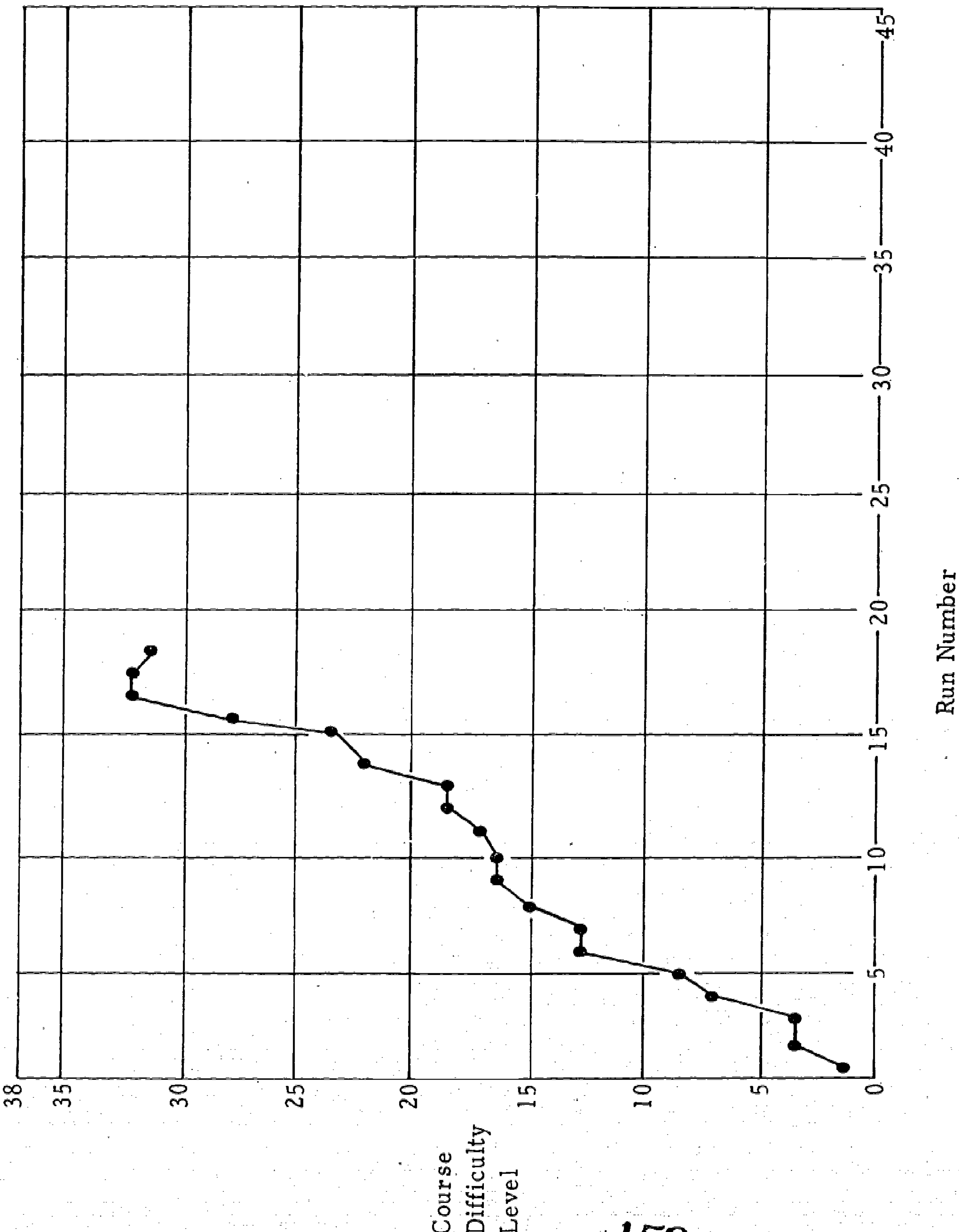


Figure 34. Plot of Runs by Pilot (Not F-4 Trained)

159

APPENDIX J

ATE QUESTIONNAIRE RESULTS

J.1 QUESTIONNAIRE RESULTS

		VG	G	S	P	U
1.	The simulator compared to the F-4 is -	1	3	7	1	-
2.	Pitch response to the stick is -	1	3	3	5	-
3.	Roll response to the stick is -	3	4	4	0	1
4.	Yaw response to the pedals is -	2	6	4	0	-
5.	Attitude control during GCA is -	1	3	4	4	-
6.	Vertical velocity control during GCA is -	0	7	4	1	-
7.	Heading control during GCA is -	4	6	2	0	-
8.	Trim Control during GCA is -	1	3	5	3	-
9.	Pre-exercise audio-tape briefings were -	5	6	1	0	-
10.	Cockpit tape briefings were -	5	7	0	0	-
11.	The quality of the voice transmission was -	4	4	4	0	-
12.	Glide slope information was -	4	1	6	1	-
13.	Course control information was -	4	5	3	0	-
14.	General information transmissions were -	4	6	2	0	-
15.	Training effectiveness for initial GCA training -	3	5	4	0	-
16.	Training effectiveness for maintaining proficiency -	4	5	3	0	-

KEY: VG - Very Good; G - Good; S - Satisfactory; P - Poor, U - Undecided

17. The training sessions were - about right - 12

18. Voice transmissions were - too often 1; about right 11

19. Glide Slope tolerances were - too tight 2; about right 10

20. Increasing difficulty of the course was - about right 12

21. Wind velocity changes were - about right 12

22. Fuel and stores changes were - about right 12

23. Turbulence changes were - too hard 3; about right 9

24. Communication failures were - partially realistic 1; realistic 11

25. Engine failures were - partially realistic 2; realistic 6

J. 2 QUESTIONNAIRE WRITTEN COMMENTS

"Excellent equipment, but flys like the F-4 simulator with some lack of stability with control inputs, particularly pitch inputs. Attitude indicator seemed overly sensitive."

"Aileron trim too sensitive - small trim change makes too large a correction in altitude. With very few small improvements everything would rate very good grades. I feel the simulator is an outstanding training aid."

"The simulation of GCA could be improved if the word outputs could be increased (possibly by the use of formed phrases instead of single words) The sequence of heading versus glide path information is such that the computer is giving heading information when glide path information is needed or vice versa. This is particularly true in the period just prior to touchdown when the criteria is more critical. An actual GCA controller will concentrate more on the element (glidepath or heading) which is seen to be varying most and needs the most concentration). The yaw encountered when an engine is lost is excessive. About half this yaw would be more realistic. Response of the simulator to fuel weight and CG is very good. Like all simulators, it is difficult to trim in pitch, although rudder and airleron trim is good. Overall, the simulation of an actual GCA in the F-4 is good."

"Cross control inputs affect the simulator much more than they affect the F-4 and the resulting motion is uncomfortable and confusing."

"1. Use a softer cushion. 2. Change the stick 'feel' to more closely simulate the F-4 or any other fighter AC. 3. Eliminate the last two difficulty levels of turbulence all together below 1000 feet. 4. Move the indexer lights closer to the center of instrument hood. 5. Reevaluate the voice drum and subsequent instructions so that unnecessary and untimely instructions are not given during critical phases (i. e. wind info at 2 miles)."

"1. The effect of the pitch stab aug should be increased to more closely simulate the characteristics of the airplane. 2. The aileron trim should be slowed down. 3. More trend information is needed on glide slope with regard to elevation. Heading information is excellent. 4. Finally and most importantly - the power/pitch relationship presents an important problem. High performance aircraft like the F-4 must be controlled in elevation on GCA final by power. The reverse effect of power/pitch in this simulator tends to build undesirable habits in this area. 5. Only room for adverse criticisms. Overall, highly enjoyable program and by far the best simulator I have flown."

"1. Pitch response too loose, i. e., after making pitch change nothing happens for a moment. 2. Roll response - simulator flys like an F-4 with roll aug off, or even 'looser' than that. 3. Turbulence is too great for realism. 4. Suggestion for window tolerances: instead of a heading correction to intersect center line 1/2 distance from present position to touchdown, suggest 1/3 of distance or 2/3 of the way out from the touchdown point."

"1. Move AOA indexers in closer to the center. 2. Put AOA indicator and flap selector as it is in the AC. 3. Pitch control is much too sensitive. 4. Tape needs to lead with its calls more. 5. Put in moveable compass card as in the F-4. 6. Repeater of GCA plot so it can be viewed after each approach."

"1. Occasionally controller gets too involved with heading and forgets glide slope. 2. Stick is too sloppy. 3. Pitch control is too sensitive. 4. Tape needs to lead its calls. Also it needs to work with trends vice position. 5. Rearrange cockpit to conform with actual cockpit, i. e. AOA indexer position, flap switch, AOA indicator and airspeed indicator positions. 6. Turbulence criteria unrealistic. 7. For students with no GCA experience, don't change configuration so often. 8. Have runs more in line with actual a/c weights. i.e. 5,000 pounds fuel, C/L tank and 2 Sparrow and 2 Sidewinder missiles. 9. Don't try to accomplish so much in one day. 10. Make heading indicator so that the compass card moves vice the needle."

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* LOGICON, INC., P. O. Box 10179, 1075 Camino del Rio S., San Diego, Calif., 92110	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP NA

3. REPORT TITLE

AUTOMATED TRAINER EVALUATION FINAL REPORT

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

None

5. AUTHOR(S) *(First name, middle initial, last name)*

John P. Charles and Robert M. Johnson

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
January 1972	154	23

8a. CONTRACT OR GRANT NO. N61339-70-C-0132	9a. ORIGINATOR'S REPORT NUMBER(S) Technical Report: NAVTRADEVCEN 70-C-0132-1
b. PROJECT NO. 8175-2	
c.	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*
d.	

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
None	Naval Training Device Center Orlando, Florida 32813

13. ABSTRACT

The automation of weapons system training presents the potential for significant savings in training costs in terms of manpower, time, and money. The demonstration of the technical feasibility of automated training through the application of advanced digital computer techniques and advanced training techniques is essential before the application of such techniques is warranted. The advanced computer techniques include the incorporation of real-time performance monitoring and course scheduling. The advanced training techniques center on the feasibility of adaptive training based on performance measurement reflecting operational performance requirements. Automated Ground Controlled Approach and emergency procedures tasks were implemented on the Naval Training Device Center-Training Device Computer System (TRADEC System) and tested with operational pilots. The results demonstrated the feasibility of automated training as well as the acceptance of the training technique by operational personnel. Recommendations for the testing of the effectiveness and efficiency of the techniques are made.

DD FORM 1 NOV 65 1473

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Adaptive Training						
Automated Training						
Training Simulation						
Automated Instructor						
GCA Training						